# CANDIDATE AND STUDY SET CRITERIA
# AND
# PROPOSED SCOPING STUDIES

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The overall purpose of the System Assessment Capability is to perform assessments of the cumulative impact of the Hanford Site post-closure waste setting. The purpose of identifying candidate and study sets is to logically define the needed technical element conceptual model(s), (e.g., waste release, vadose zone), and thereby initiate their development and incorporation into the System Assessment Capability. The candidate set criteria serve to define the complete list of items or processes that comprise the candidate set. The study set criteria serve to define the contaminants, transport processes, etc., needed in the decision-assisting system assessment capability.

Columbia River Comprehensive Impact Assessment (CRCIA) Part 2 calls for the creation of candidate and study sets to define the contaminants, inventories, processes, geologic structures, hydraulic properties, etc., that comprise an assessment of impacts to the Columbia River from the Hanford Site. This methodology or CRCIA template has been adopted to formulate a system assessment capability which will be improved iteratively and provide an assessment of Hanford Site waste disposals and remediation impacts to all water resources. These resources include the unconfined aquifer beneath the Hanford Site and the Columbia River. During the winter quarter of fiscal year 1999, this process was initiated by drafting criteria for candidate and study sets. In addition, some technical elements identified scoping studies necessary for the identification of candidate set entries or the reduction of candidate sets to study sets. The CRCIA requirements outline the need for seventeen candidate sets ranging from the Candidate Contaminant Set to the Candidate Scenarios Set.

A System Assessment Capability (SAC) Work Group meeting was held on 24 February 1999, and the draft criteria for candidate and study sets, and the proposed scoping studies were presented. Comments from the work group members were solicited and recorded at the meeting. Participants were asked to send any written comments or recommended changes to the criteria and proposed scoping studies by March 24. Since the meeting, no comments have been received on the criteria and proposed scoping studies, and the criteria are now being finalized based on comment received at the meeting. This summary and the revised statements of criteria and proposed scoping studies will be put on the web site for general reference by the GW/VZ Integration Project.

## WORKING RULES AND OBSERVATIONS

There are several rules or observations that applied to virtually all of the candidate and study set criteria. They are presented below. The reader is referred to the individual technical element text, (e.g., see Appendices on Inventory and Release, Vadose Zone, Groundwater), for other rules and observations for individual technical elements.

Statement of Inclusion

It is recognized that the development of candidate and study set criteria and parameters is iterative. As parameters or processes are identified that may have been left out of a given set, they will be added to the appropriate set and criteria modified, as necessary. Though the goal of developing a candidate set is to be complete, it is recognized that any list, by its nature of being a list, is not complete. The GW/VZ Project must balance the need for completeness with the needs of the assessment.

Multiple Study Sets

It is recognized that the development of criteria for study sets is iterative and will depend on information from other technical elements. The purpose of the study set must be clearly stated to allow its development. Multiple purposes will require multiple study sets.

Documentation

All sources of information must be identified. Any assumptions must be explicitly identified and defended. This is particularly important for items intentionally given low priority in the initial assessments.

Level of Explicitness

It is recognized that data will be lacking for many possible contaminants at many waste sites. It is acceptable for some aggregation of study sets, (e.g., waste site types, either in space, by source, or other common category), in early iterations of the SAC. Any aggregations will be explicitly defined and rational provided.

## TECHNICAL ELEMENTS

To focus the development of criteria and scoping studies, eight technical elements were identified and staffed. They were the inventory, vadose zone, groundwater, Columbia River, atmosphere, risk and impact, assessment scenarios, and Hanford Site disposition baseline. These eight technical areas were assigned the seventeen candidate set topics named in CRCIA Part 2 (Appendix A) and the newly identified set of candidate Hanford Site end states. The technical elements, candidate sets, and staff assigned to author the criteria and proposed scoping study statements are summarized in Table 1.

The technical element write-ups for the first seven technical elements are attached as appendices. Completion of the last technical element write-up, (i.e., Hanford Site disposition baseline), will follow completion of an ongoing review of end-state assumptions employed in the Hanford Site closure-cost estimate. Because of the level of detail captured in each technical element, no attempt has been made here to summarize the criteria. The reader is referred to the appendices for that information. In addition to criteria and proposed scoping studies, the technical element text includes a cross-walk to the CRCIA Part 2 Appendix A requirements. The criteria and proposed scoping studies under the topic Risk and Impacts reflect significant contributions from B Harper of the Yakama Indian Nation and S Harris of the Confederated Tribes of the Umatilla Indian Reservation.

Table 1. The matrix of technical elements, candidate sets, and staff assigned.

| Technical Element | Candidate Sets | Staff |
|---|---|---|
| Inventory | Candidate Contaminant Set (A1.1)<br>Candidate Inventories Set (A1.2)<br>Candidate Contaminant Failure Set (A2.1) | BA Napier*<br>MI Wood<br>LW Vail<br>RJ Serne |
| Vadose Zone | Contaminant Transport Paths Set (A3.1) | GW Gee*<br>CR Cole<br>LW Vail<br>RJ Serne |
| Groundwater | Contaminant Transport Paths Set (A3.1) | CR Cole*<br>RJ Serne |
| Columbia River | Candidate River Entry Location Set (A4.1)<br>Candidate River Holdup Location Set (A5.1)<br>Candidate Habitat Location Set (A6.1)<br>Candidate Habitat Features Set (A6.2) | RL Dirkes*<br>R Peterson<br>MC Richmond |
| Atmosphere | Contaminant Transport Paths Set (A3.1) | BA Napier*<br>JV Ramsdell, Jr. |
| Risk and Impact | Candidate Receptors Set (A7.1)<br>Candidate Exposure Mechanism Set (A7.2)<br>Candidate Pathways Set (A7.3)<br>Candidate Cultural Dependency Webs Set (A7.4)<br>Candidate Receptors of Concern Set (A7.5)<br>Candidate Dose Measures Set (A8.1)<br>Candidate Dose Attributes Set (A8.2)<br>Candidate Impact Set (A9.1) | PG Doctor*<br>BA Napier |
| Assessment (Extreme) Scenarios | Candidate Scenarios Set (A10.1) | AL Bunn*<br>LW Vail |
| Hanford Site Disposition Baseline | Candidate Hanford End State Set** | CT Kincaid* |

* Indicates the lead staff member responsible for submittal of the text

** Completion of this candidate set is dependent on development of a clear statement of the assumed end states for the Hanford Site that form the basis of the cost to closure estimate. The assumed end states are being assembled as part of the system engineering analysis of the GW/VZ Integration Project and the SAC task within the Project.

## FUTURE APPLICATION

At present, scoping studies have been undertaken on the topics of inventory and risk/impacts. For the purpose of producing an initial SAC, (i.e., Rev 0), as early as possible, it has been decided that assessment capabilities for release and environmental pathway technical elements will be based largely on existing technology. Where existing technologies do not present an estimate of uncertainty, they will be adapted to do so. Thus, the SAC, Rev 0, may be based on study sets derived from existing capabilities modified to provide uncertainty estimates.

It is important that all assumptions, their technical basis, and all technical issues requiring closure be identified during the process of identifying and adopting existing capabilities. This will be accomplished by preparing a document on the selection of the conceptual model(s) for each technical element. If identified as research necessary to close technical issues identified in the conceptual model white papers, the Project will undertake to fill that need. The research efforts will form the basis for a series of scoping studies necessary to both close issues and fully justify conceptual models of the waste release and the environmental migration and fate of contaminants. Once a listing of research efforts is assembled, they will be prioritized and resources will be sought to support those efforts needed to provide the necessary technical basis for future versions of the SAC.

The assumptions and their technical basis, and the technical issues and their associated research identified in the conceptual model white papers will be consistent with the criteria and proposed scoping studies of the attached technical element appendices. The criteria identified in the technical element appendices will be revisited and applied to identify the waste contaminants, waste inventories, transport processes, etc., for future iterations of the SAC. Thus, the assumptions and their technical basis for using a given conceptual model must be consistent with the criteria proposed to reduce a candidate set to a study set and thereby identify a conceptual model. Similarly, the scoping studies proposed to apply study set criteria and identify a conceptual model must be consistent with the studies needed to resolve technical issues and provide technical support for a given conceptual model. Thus, while the development of candidate and study sets is not being achieved in the serial manner envisioned in CRCIA Part 2, the approach being taken under the Gw/Vz Integration Project to develop the SAC is not inconsistent with the intent CRCIA process.

## GLOSSARY

Candidate Set:  A compilation of all relevant factors assembled in accordance with criteria that ensure demonstrable completeness.

Candidate Set Criteria:  The rules for generating the candidate set.

Scoping Study:  A study to assemble data and information, and possibly conduct an initial screening assessment, needed to reduce a candidate set to a study set.

Study Set:  A subset of the corresponding candidate set that is to be used for the assessment analysis.  Elements of the study set are to be represented explicitly in the assessment analysis.  The study set is uniquely defined for one or more iterations of the system assessment capability.

Study Set Criteria:  The rules for reducing the candidate set to the study set.

**APPENDIX A. INVENTORY AND RELEASE**
**BN NAPIER, MI WOOD, LW VAIL, RJ SERNE**

## CRITERIA FOR CONTAMINANTS AND INVENTORIES (CRCIA A1.1, A1.2)

***WORKING RULES AND OBSERVATIONS***

1. Statement of Inclusion: It is recognized that the development of candidate and study set criteria and parameters is iterative. As parameters are identified that may have been left out of a given set, they will be added to the appropriate set and criteria modified, as necessary. Though the goal of developing a candidate set is to be complete, it is recognized that any list, by its nature of being a list, is not complete. The GW/VZ Project must balance the need for completeness with the needs of the assessment.

2. Multiple Study Sets: It is recognized that the development of criteria for study sets will also be iterative and depend on information from other technical elements. The purpose of the study set must be clearly stated to allow its development. Multiple purposes will require multiple study sets.

3. Documentation: All sources of information must be identified. Any assumptions must be explicitly identified and defended. This is particularly important for items intentionally given low priority in the initial assessments.

4. Level of Explicitness: It is recognized that data will be lacking for many possible contaminants at many waste sites. It is acceptable for some aggregation of waste site types, either in space, by source, or other common category. Any aggregations will be explicitly defined and rational provided.

## Criteria for the Contaminants Candidate Set

A two-part approach was taken to develop contaminant candidate set criteria, one for radionuclides and one for chemicals.

> *CRCIA Part II – The set of all identifiable masses of materials and contaminants that could case harmful effects to humans, ecosystems, or cultures.*

### *1 Radionuclides*

Any Hanford produced or imported radionuclide in excess of 1 curie (when generated or imported) and with a half life greater than 5 years will be considered.

### *2 Chemicals*

Anything imported, manufactured, or produced (*note: produced is meant to represent secondary products or waste*) at Hanford for use in operations or disposal, as well as any additional contaminant identified in the monitoring and characterization programs will be considered. (*Note -this criterion captures the principles of chemicals purchased and brought onto the site and changes in chemicals brought on by chemical and biological activity*).

## Criteria for the Inventory Candidate Set

> *CRCIA Part II – The set that identifies all the inventories whose contributions to harmful effects are potentially of concern.*

### *1 Locations*

Any locations or facilities of known past or proposed future radionuclide or chemical processing, storage, disposal, or accidental release will be considered. Locations with unique materials will be given particular attention.

### *2 Contaminants*

The locations must contain quantities of the contaminants identified in the Candidate Contaminants Set.

### *3 Physical State*

A physical description of each location must be provided.

## Study Set Criteria

> *CRCIA Part II – A subset of the corresponding candidate set that is to be used for the assessment analysis. Elements of the study set are to be represented explicitly in the assessment analysis. It is uniquely defined for one or more iterations of the assessment analysis. An … example is the Inventory Study Set which is a subset of the Candidate Inventories.*

Study sets are defined for use in the problem at hand. The purpose of the study set must be clearly stated and agreed upon. The overall purpose of the System Assessment Capability efforts is to perform a cumulative assessment of Hanford impacts. The purpose of the Study Sets is to allow development of the System Assessment Capability and support a first-iteration demonstration (proof-of-principle) assessment by the end of Fiscal Year 2000. The Study Sets must include those sites containing radionuclides and chemicals that are important to human and ecological health, socio-economic and cultural impacts, and system modeling and validation. Because the Contaminant and Inventory Study Sets are intimately linked through contents at specific locations, the criteria are interrelated.

Depending on the purposes of future assessments, differing contaminants and/or locations from the candidate sets could be selected in future iterations.

The purpose of the Study Set results in some implicit criteria as well as the more-formally defined explicit criteria. Supporting the concept of documentation of assumptions, these are listed below.

### *Implicit Criteria*

The intent to complete a first iteration of the System Assessment Capability and a demonstration system assessment indicates that the selection of the study sets must be completed within a relatively short period. This implies a limited ability to meet the expressed desire to be comprehensive; it will not be possible to fully evaluate all historical Hanford operations and releases in this limited time. Therefore, the initial study set will be prepared in parallel with, and primarily in advance of, a more complete effort.

The initial study sets must use relatively readily-available data sources.

The process for developing the initial study sets must be compatible with, and extensible to, the larger effort.

### *Explicit Criteria*

The approach involves a screening assessment that:

1) identifies a performance indicator (like risk),
2) conducts a screening analysis, and
3) selects those contaminants comprising more than 1% of the indicator (in accordance with the concept of dominance), over some accepted threshold value.

The locations of processing or waste handling will be incorporated into the screens.

The performance indicators fall into the categories of human health, ecological health, socio-economic and cultural impact, modeling requirements and validation, regulatory drivers, and public interest. Because there is a large number of source locations and all source locations may not be equally important with respect to system impact, a process for focussing efforts on key sites is developed. The Contaminants Study Set and the Inventories Study Set are prioritized. Essentially the same criteria and processes used to prioritize the contaminants are used to rank the inventories. The scoping studies for Contaminant and Inventory Study Sets will be coordinated and usually combined into one analysis.

Screening analyses will consider concentrations in soil, groundwater, Columbia River water, and biota. A simplified screening model will be developed to predict potential maximal concentrations in these media from their current locations (e.g., National Council on Radiation Protection and Measurements Report No. 123, *Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground*). Quantities of potential contaminants of concern will be estimated for aggregate waste site groupings based on geographic location and common physical conditions (e.g., solubility).

## Criteria for the Contaminants Study Set

> *CRCIA Part II – A subset of the corresponding candidate set that is to be used for the assessment analysis. Elements of the study set are to be represented explicitly in the assessment analysis. It is uniquely defined for one or more iterations of the assessment analysis. An example is the Contaminants Study Set which is a subset of the Candidate Contaminants Set.*

### *1 Human Health*

Individual risk of cancer, evaluated using a consistent exposure scenario for all media that includes exposures at various ages to several common exposure pathways, will be estimated with Cancer Potency Factors from the Health Effects Assessment Summary Tables (or an appropriate substitution made) for chemicals and from Federal Guidance Report 13 for radionuclides.

Individual non-cancer effects, evaluated using a consistent exposure scenario for all media that includes exposures at various ages to several common exposure pathways, will be estimated with Reference Doses from the Health Effects Assessment Summary Tables (or an appropriate substitution made) for chemicals.

For both cancer and non-cancer effects, the total impact to an individual at the highest combined concentration/impact times will be considered to be the summed risk or hazard index. The contaminants which together provide the bulk of the impact (greater than 1% each) will be considered to have passed the screen and be included in the Study Set.

### *2 Ecological Health*

Ecosystem toxicity and sub-lethal effects will be considered via comparison of estimated concentrations to Lowest Observed Effects Levels (LOELs). For those materials for which values are available, Water Quality Criteria will also be compared against.

The total impact to the environment at the highest combined concentration/ impact times will be considered to be the summed ratios of concentration to LOEL. The contaminants which together provide the bulk of the impact (greater than 1% each) will be considered to have passed the screen and be included in the Study Set.

### *3 Socio-cultural Effects*

The concepts of loss-of-use, loss of religious or spiritual value, and intangible mental stress are all related to the possible contamination of environmental materials. The Lower Limit of Detection (LLD) available through current conventional laboratory techniques will be considered as the benchmark; predicted environmental contaminant concentrations in groundwater, river water, and aquatic biota as prepared for the human health and ecological health calculations will be compared to the appropriate LLD.

Those materials for which predicted Hanford-related incremental concentrations exceed the LLD will be ranked, and all those above a threshold value (to be determined) will be included in the Study Set.

### *4 Modeling Requirements and Validation*

Materials present in waste streams that affect the transport or mobility of other contaminants will be included as contaminants to support the modeling efforts. Materials with documented impacts will be included. This will include materials that make up the bulk of contaminant mass – low level trace materials will not be included. Examples include sodium, aluminum, and "organic complexants" as a class.

Contaminants that have available historical measurements in sufficient quantity to provide a basis for comparisons of predicted versus modeled environmental concentrations will be included, even if they do not pass the previous screens. Examples could include tritium in groundwater or ruthenium-106 in vadose zone soils. Selection will be made on the number of measurements available over time and the mechanisms that are to be validated, based on interactions of the staff of the various Transport Technical Elements with the Inventory Technical Element.

### *5 Regulatory Drivers*

Appendix E of the Groundwater/Vadose Zone Integration Project Specification (DOE/RL-98-48) lists the pertinent federal and state laws and regulations applicable to the Hanford Site cleanup activities. Many of these applicable laws and regulations specify allowable concentrations of certain materials. The most basic generally are the regulations based on the Safe Drinking Water Act of 1974, including the National Primary Drinking Water Standards 40CFR141, and

Washington State rules derived from it such as the Model Toxics Control Act WAC 170-340-700. These rules refer to the Maximum Contaminant Levels and Maximum Contaminant Level Goals (MCL and MCLG). For the Contaminant Study Set, those contaminants for which the existing or predicted concentrations exceed the MCLs will be included.

### *6 Public Interest*

Potential Hanford contaminants will be evaluated using the prior screens. Through an agreed upon screening process, candidate contaminants will be narrowed down to a study set. Some contaminants eliminated through this process may still be of significant tribal, stakeholder, and/or public interest or concern. If these concerns are not adequately addressed by existing project rational, then additional scoping studies or criteria may be necessary to justify including the contaminant in the assessment. The scoping studies will be designed, reviewed, and conducted consistent with established GW/VZ Integration Project protocols, including appropriate technical reviews and tribal, stakeholder, and public involvement.

## Criteria for the Inventory Study Set

### *1 Human Health*

Individual risk of cancer, evaluated using a consistent exposure scenario for all media that includes exposures at various ages to several common exposure pathways, will be estimated with Cancer Potency Factors from the Health Effects Assessment Summary Tables (or an appropriate substitution made) for chemicals and from Federal Guidance Report 13 for radionuclides.

Individual non-cancer effects, evaluated using a consistent exposure scenario for all media that includes exposures at various ages to several common exposure pathways, will be estimated with Reference Doses from the Health Effects Assessment Summary Tables (or an appropriate substitution made) for chemicals.

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The total impact to the environment at the highest combined concentration/impact times will be considered to be the summed ratios of concentration to LOEL. The contaminants which together provide the bulk of the impact (greater than 1% each) will be considered to have passed the screen and be included in the Study Set.

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Those materials for which predicted Hanford-related incremental concentrations exceed the LLD will be ranked, and all those above a threshold value (to be determined) will be included in the Study Set.

### *4 Modeling Requirements and Validation*

Materials present in waste streams that affect the transport or mobility of other contaminants will be included as contaminants to support the modeling efforts. Materials with documented impacts will be included. This will include materials that make up the bulk of contaminant mass – low level trace materials will not be included. Examples include sodium, aluminum, and “organic complexants” as a class.

Contaminants that have available historical measurements in sufficient quantity to provide a basis for comparisons of predicted versus modeled environmental concentrations will be included, even if they do not pass the previous screens. Examples could include tritium in groundwater or ruthenium-106 in vadose zone soils. Selection will be made on the number of measurements available over time and the mechanisms that are to be validated, based on interactions of the staff of the various Transport Technical Elements with the Inventory Technical Element.

### *5 Regulatory Drivers*

Appendix E of the Groundwater/Vadose Zone Integration Project Specification (DOE/RL-98-48) lists the pertinent federal and state laws and regulations applicable to the Hanford Site cleanup activities. Many of these applicable laws and regulations specify allowable concentrations of certain materials.  The most basic generally are the regulations based on the Safe Drinking Water Act of 1974, including the National Primary Drinking Water Standards 40CFR141, and Washington State rules derived from it such as the Model Toxics Control Act WAC 170-340-700.  These rules refer to the Maximum Contaminant Levels and Maximum Contaminant Level Goals (MCL and MCLG).  For the  Contaminant Study Set, those contaminants for which the existing or predicted concentrations exceed the MCLs will be included.

### *6 Site Grouping*

Waste disposal sites may be considered collectively based on the process streams that have been discharged to them, physical proximity, and hydrogeological setting.  For example, wastewater disposal cribs at PUREX might be grouped, but separately from wastewater disposal cribs at REDOX. Similarly, inventories within tanks at a single tank farm could be grouped, but separately from the materials in the vadose zone that have leaked from those same tanks.

### *7 Physical State*

A description of the contaminated area/volume, including approximate dimensions, physical form of material when released/emplaced (liquid, solid, powder, etc.), temperature, or other important characteristics will be provided.

## Anticipated Scoping Studies

The implementation of the sets of criteria defined above for selecting the Contaminants and Inventory Study Sets from the Candidate Sets requires a scoping study.  This scoping study is needed to develop the screening methods and collect and document the supporting information.  It is anticipated that the scoping study for Inventories would be coordinated with and complementary to that for Contaminants.

The first task of the scoping study, somewhat independent of the others, will collect and organize the  Contaminants and Inventory Candidate Sets.  Existing records and estimates will be reviewed, and additional calculations made as necessary.  For radionuclides, this will entail estimates of total radionuclide activities produced at Hanford, using ORIGEN II and historical production activities.  For major chemical use, the bismuth phosphate, REDOX, and PUREX process chemical flowsheets and reactor operations histories will be reviewed and estimates made based on irradiated metal throughput.  Most of the necessary information should be available from the tank waste inventory estimates and the Hanford Environmental Dose Reconstruction Program.

Several of the proposed criteria require estimates of projected environmental contaminant concentration. A second task will develop a simple, robust method for projecting groundwater, river water, and biota concentrations based on inventory estimates. This model will be for screening only. The starting point will be the radionuclide models described in National Council on Radiation Protection and Measurements Report No. 123, *Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground*. These simple models will be expanded to deal with chemical contaminants as well. The resulting models are anticipated to give results similar to those of CRCIA Part 1.

The third task of the scoping study will combine the inventory estimates of the first study, and the transport model of the second, into a spreadsheet with cancer potency factors, radiation risk factors, reference doses, LOELs, and LLDs. It is anticipated that the ranking techniques will be similar to those used in CRCIA Part I. The ranked results of the calculations will provide the numerical inputs for the selection of the Contaminants and Inventories Study Sets. This effort will also evaluate regulatory drivers and work with project staff to define model validation data requirements.

Assuming approval to initiate work on the scoping studies in late February, the Contaminants and Inventories Study Sets will be presented for review in April 1999. Approximately 6 person-months of effort are anticipated. The primary executor of the work will be PNNL, but staff of other Hanford contractors will be requested to participate at a low level of effort.

## Relationship to CRCIA Part II Requirements

The relationship of the proposed Contaminant Candidate Set criteria and Contaminant Study Set criteria are illustrated in the following table derived from CRCIA Part II Appendix II-A.

| CRCIA REQUIREMENTS | | Incorporated in Criteria? |
|---|---|---|
| Appendix II-A: What the Assessment Must Include | | |
| | | |
| A.1 Hanford Materials and Contaminants (Sources and Inventories) | | |
| (A1.0-1) | All existing and potential contaminants and contaminant sources shall be identified, characterized, and ranked for significance of potential impact. The characterization shall include atomic or molecular composition, mass, and location. It also shall include reactivity, solubility, and mobility. Materials shall be defined explicitly enough to support tracing their movement through the media along their pathway to the Columbia River. | Yes – Candidate Set Criteria 1 and 2 |
| (A1.0-2) | A method shall be developed to demonstrate and document completeness of the lists of inventory sources and their compositions used in the assessment. | The concept underlies the criteria for the candidate set – will be addressed iteratively. |
| A.1.1 Required Candidate Contaminants Set | | |
| (A1.1-1) | The Candidate Contaminants Set shall be formed by identifying all the radioisotopes and chemicals that are known to have a harmful impact on humans, cultures, or ecosystems and are known to be on the Hanford Site, as determined by established criteria. | Yes – Candidate Set Criteria 1 and 2 plus Study Set Criteria 1,2, and 3 |
| (A1.1-2) | Criteria for the completeness of the range of contaminants to be included in the Candidate Contaminants Set shall be established in consultation with the System Assessment Capability Team and shall be subject to its approval. | This process is ongoing |
| (A1.1-3) | Chemicals that mobilize contaminants shall be included in the Candidate Contaminants Set. An example is ethylenediamine-N,N,N',N'-tetra acetic acid (EDTA). | Yes – Candidate Set Criterion 2 plus Study Set Criterion 4 |

The relationship of the proposed Inventory Candidate Set criteria and Inventory Study Set criteria are illustrated in the following table derived from CRCIA Part II Appendix II-A.

| CRCIA REQUIREMENTS | | Incorporated in Criteria? |
|---|---|---|
| | | |
| Appendix II-A: What the Assessment Must Include | | |
| | | |
| A.1 Hanford Materials and Contaminants (Sources and Inventories) | | |
| (A1.0-1) | All existing and potential contaminants and contaminant sources shall be identified, characterized, and ranked for significance of potential impact. The characterization shall include atomic or molecular composition, mass, and location. It also shall include reactivity, solubility, and mobility. Materials shall be defined explicitly enough to support tracing their movement through the media along their pathway to the Columbia River. | Yes – Candidate Set Criteria 1 and 2 |
| (A1.0-2) | A method shall be developed to demonstrate and document completeness of the lists of inventory sources and their compositions used in the assessment. | The concept underlies the criteria for the candidate set – will be addressed iteratively. |

| A.1.2 Required Candidate Inventories Set | | |
|---|---|---|
| (A1.2-1) | The Candidate Inventories Set shall be formed by identifying all the inventories that contain any contaminants belonging to the Candidate Contaminants Set, as determined by established criteria. | Yes – Candidate Set Criterion 2 |
| | **a.** Present inventories and those to be added by future missions shall be included. | Yes – Candidate Set Criterion 1 |
| | **b.** All inventories on the Hanford Site shall be included regardless of who owns or is responsible for them. Although not complete, the following are examples of inventories that shall be included: | Yes– Candidate Set Criterion 1 |
| | residual pre-1970 transuranic solid waste | Example |
| | burial grounds waste, such as that contained at 618-10 and 618-11 | Example |
| | Non-Radioactive Dangerous Waste Landfill | Example |
| | projected mass of contaminants from the Environmental Restoration Disposal Facility | Example |
| | submarine reactor cores | Example |
| | Resource Conservation and Recovery Act (RCRA) storage and disposal sites | Example |
| | U.S. Ecology Incorporated site | Example |
| | Advanced Nuclear Fuels at the Siemens Power Corporation site | Example |
| | Washington Public Power Supply System materials and contaminants | Example |
| | laundries handling anti-contamination clothing | Example |
| | residual waste inventory from the Liquid Effluent Retention Facility and similar treatment facilities | Example |
| | routine permitted releases, such as National Pollution Discharge Elimination System (NPDES) or National Emission Standards for Hazardous Air Pollutants (NESHAP) | Example |
| | spent nuclear fuel storage sites, such as K Basins, including water, sludge, and structure | Example |
| | inventories associated with retention basins | Example |
| | inventories associated with 100 Area reactors, including reactor cores | Example |
| | inventories associated with T-Plant facilities | Example |
| | inventories associated with B-Plant facilities and cesium capsules | Example |
| | inventories associated with Plutonium Uranium Extraction (PUREX) facilities | Example |
| | inventories associated with Fast Flux Test Facility (FFTF) facilities | Example |
| | special nuclear materials inventories, including N Reactor spent fuel and the proposed spent nuclear fuel inventory for the Containment Storage Building | Example |
| | groundwater inventories, for example, dense and light phase non-aqueous liquid inventories | Example |
| | saturated zone inventories on soils | Example |
| | contaminants inventories in liquid effluent disposal facilities, such as cribs and French drains | Example |
| | inventories associated with decontaminated and decommissioned facilities | Example |
| | inventories associated with interim stabilized facilities | Example |
| | **c.** Residual materials (contaminants) expected to remain on the Hanford Site after retrieval and after remedial goals have been met shall be included. Although not complete, the following are examples of inventories that shall be included: | Yes– Candidate Set Criterion 1 |
| | contaminant inventories expected to remain in the saturated zone | Example |
| | material inventories expected to remain in tank structures | Example |
| | contaminant inventories expected to remain in the vadose zone, including those located below excavation depth | Example |
| | contaminated sediment inventories expected to remain in the Hanford Reach, including sloughs | Example |
| | parent contaminants and their degradation and reaction products, such as chromium (including Cr III and Cr VI), carbon tetrachloride, trichloroethylene (TCE), and TCE degradation products | Example |

| | | |
|---|---|---|
| | materials known to have been produced but lost to the accessible environment | Example |
| | **d.** Inventories that contaminate the following locations shall be included: | Yes– Candidate Set Criterion 1 |
| | lower Columbia River shoreline and sediment from McNary Dam to the Pacific Ocean | Example |
| | McNary Pool shoreline and sediment | Example |
| | lower Columbia River dams pool sediment | Example |
| | tidal area sediment at the mouth of the Columbia River | Example |
| | Port of Pasco and Kennewick sediment | Example |
| | shoreline at the 300 Area | Example |
| | shoreline between the Hanford town site and land leased by the Washington Public Power Supply System | Example |
| | shoreline at the Hanford town site | Example |
| | shoreline at the 100 Area | Example |
| | North Slope shoreline | Example |
| | upstream of the 100 Area | Example |
| | **e.** Inventories created by hazardous materials introduced in the course of cleanup activities shall be included. An example is the material inventories accumulated from in-situ REDOX projects and that might be released at undesirable concentrations in the future, such as uranium at breakdown of the REDOX barrier. | Yes - Candidate Set Criterion 1 |
| (A1.2-2) | Criteria for determining the completeness of the range of inventories to be included in the Candidate Inventories Set shall be established in consultation with the System Assessment Capability Team and shall be subject to its approval. | This process is ongoing |
| (A1.2-3) | Inventory masses shall be established and reconciled with known reactor production quantities and chemical input to the Hanford Site. Estimates of lost materials that may remain in the local environment shall be included in the reconciliation. | Proposed scoping study |
| (A1.2-4) | Decay of radionuclides and production of radioactive daughters shall be accounted for in inventories and throughout their transport to the Columbia River and uptake by receptors. | Yes |

### CRITERIA FOR CONTAINMENT FAILURE/CONTAMINANT RELEASE SCENARIOS SET (CRCIA A2.1)

## *2 Working rules and observations*

1. Contaminant release rates from a waste site or disposal facility are, at a minimum, a function of waste material or waste form leaching characteristics in the site-specific surrounding environment. Depending on the specific waste site, engineered barriers may also be present that delay or affect release rates and overall contaminant fluxes.

2. No waste forms are expected to prevent contaminant migration over all time. To evaluate potential future environmental contamination, a finite release rate of contaminants from waste materials or waste forms is assumed.

3. Definition of release scenarios is dependent upon the composite end states of all waste disposal sites as defined in the Hanford Site Disposition baseline (CRCIA A.11). The baseline will define the waste state including waste form, anticipated stability, and nature and description of barriers, if applied.

4. A complete assessment will include not only the anticipated ("design basis") performance of all waste sites but also stochastic or parametric (deterministic with different parameters) variations that will include times to failure and failure rates that vary.

5. Statement of Inclusion: It is recognized that the development of candidate and study set criteria and parameters is iterative. As parameters are identified that may have been left out of a given set, they will be added to the appropriate set and criteria modified, as necessary. Though the goal of developing a candidate set is to be complete, it is recognized that any list, by its nature of being a list, is not complete

### CRITERIA FOR CONTAINMENT FAILURE/CONTAMINANT RELEASE CANDIDATE SCENARIOS SET

*CRCIA Part II – A Candidate Failure Scenarios Set identifies all the scenarios contributing to contaminant release into the adjacent environment*

1. For each disposal site or waste grouping, releases resulting from projected performance (design basis) will be included.

2. For each disposal site or waste grouping, waste release mechanisms appropriate to the particular waste material or waste form will be selected to estimate release rates.

3. For each disposal site or waste grouping which includes engineered barriers that provide containment, a time of containment failure or a distribution of containment failure will be included.

4. For each disposal site or waste grouping, releases resulting from future climatological conditions will be included (e.g., increased regional precipitation at some future time).

5. For each disposal site or waste grouping which includes engineered barriers, enhanced releases resulting natural degradation (wearing out) will be included (e.g., chemical degradation of liner materials, weathering of barrier materials).

6. For each disposal site or waste grouping, releases resulting from human disruption will be included (e.g., fractionally increased leach rates evaluated for inadvertent or intentional penetration of barriers).

**CRITERIA FOR THE INITIAL CONTAINMENT FAILURE/CONTAMINANT RELEASE STUDY SET**

> *CRCIA Part II – A subset of the corresponding candidate set that is to be used for the assessment analysis.*

1. All waste disposal sites or groups will be evaluated for releases resulting from projected performance (design basis).

2. One waste release mechanism and associated release rate value will be selected for each waste site or waste grouping. If more than one release mechanism is plausible, the one yielding the best estimate flux estimate will be selected.

3. For each disposal site or waste grouping which includes engineered barriers that provide containment, distributed containment failure will be considered if relevant field data are available as a basis for estimating quantifiable distribution. Otherwise, instantaneous failure and a minimum time of failure after placement of the containment barrier will be considered.

4. For each disposal site or waste grouping, a minimum number (generally 1) of releases will be estimated for degraded conditions, either waste form and/or engineered barriers). The release scenario will consider only a deterministic estimate of enhanced contaminant flux. Probabilistic or statistical release functions will be used only if relevant data are available as a basis for estimating the variable release conditions and releases.

## ANTICIPATED SCOPING STUDIES

The criteria defined above for selecting the Containment Failure/Contaminant Release Study Set require definition of the anticipated end states of the various Hanford waste forms. It is expected that this definition will be made by the Hanford Site Disposition Baseline technical element.

The study set criteria lead to a minimum set of study set conditions, thereby removing the need to reduce the number of possible options to select. Consequently, no scoping studies are anticipated.

## RELATIONSHIP TO CRCIA PART II REQUIREMENTS

The relationship of the proposed Candidate Set criteria and the initial Containment Failure Study Set criteria are illustrated in the following table derived from CRCIA Part II Appendix II-A.

| A.2 Containment Failure and Contaminant Release | | |
|---|---|---|
| (A2.0-1) | A projected time of containment failure for each isolation form shall be determined based on the method of containment selected in the approved disposal plan. If disposal plans (see Section II-A.11) include defensible estimates of containment durability, these will be used. It is anticipated that uncertainties in time to containment failure for a disposal form will require representation in terms of statistical distributions. Distributions may need to be parameterized on isolation form attributes, depending on the specificity of isolation form definitions. Examples of attributes are the type of barrier and glass formulation applied. | Candidate Set Criteria 1, 2 ,3, 4, 5 and 6<br>Study Set Criteria 1, 2, 3 |
| (A2.0-2) | The projected rates of release from each form of isolation after containment failure (progression of containment deterioration) shall be determined based on approved disposal plans, where available, according to Section II-A.11. | Candidate Set Criteria 1, 2, 3, 4, 5 and 6<br>Study Set Criteria 1, 2, 3 |
| (A2.0-3) | Determination of release rates shall be consistent with external migration rates in adjacent soils. | Requires coordination with Vadose Zone modeling |
| (A2.0-4) | The following shall be included in formulating shallow land burial site evaluations: | |
| | a. The engineered barrier description used in the assessment shall be the "Hanford Site Disposition Baseline" (see Section II-A.11) as approved by the responsible agency (DOE, Ecology, EPA, Washington Public Power Supply System) and the appropriate regulatory agency. Where no baseline exists, the guidance of the responsible agency shall be used with regulator concurrence. | II-A.11 Criteria |
| | b. Approved barriers and other mobility inhibiting actions, as well as barrier failure scenarios, shall be included. | II-A.11 Criteria |

| | | |
|---|---|---|
| | c. Migration of Hanford contaminants under all applicable types of barriers in non-uniform geologic media shall be included. An example of this is accelerated lateral dispersion due to caliche layers. | II-A.3 Criteria |
| A.2.1 Required Candidate Containment Failure Scenarios Set | | |
| (A2.1-1) | The Candidate Containment Failure Scenarios Set shall be formed by identifying all the individual containment failure scenarios, both those with high likelihood and those that possibly could lead to the shortest containment failure time and initial contaminant release and/or the highest rate of contaminant release following containment failure. | Candidate Set Criteria 1, 2, 3, 4, 5 and 6;<br>Study Set Criteria 1, 2 and 3 |
| (A2.1-2) | Criteria for determining the completeness of the range of containment failure scenarios to be included in the Candidate Containment Failure Scenarios Set shall be established in consultation with the System Assessment Capability Team and shall be subject to its approval. | Ongoing process |

**APPENDIX B. VADOSE ZONE**
**GW GEE, CR COLE, LW VAIL, RJ SERNE**

# Vadose Zone Technical Element

# Candidate and Study Sets for SAC

## *Introduction*

Development of candidate and study set criteria is dynamic and iterative. As additional parameters and more site specific data are obtained they will be included in the appropriate study set and the criteria modified as necessary. The goal of developing a candidate set is to make the assessment technically complete and comprehensive, yet this goal may be elusive since stakeholders and technical experts may not agree on the degree of completeness at any given time. The VZ/GW program must balance the need for completeness with practicality, availability of data, and acceptance by the stakeholders involved. All aspects of the development of candidate and study sets will be maintained in a permanent record that will capture issues, evaluations, prioritizations, and decisions.

The purpose of the study set will be site and need specific and will be clearly stated in order to allow its full development. Multiple purposes may require multiple study sets. All sources of data input must be clearly identified and assumptions explicitly defended. Justification should be provided for those items given low priority in the initial assessment.

Data will be lacking for much of the vadose zone where the analysis will be focused. Scale-up and volume averaging will be required. The justification of upscaling and averaging will need to be evaluated either deterministically or by way of a probabilistic assessment that clearly reflects the uncertainties involved in the analysis.

### *Criteria for the Vadose Zone Candidate Set*

Criteria for determining completeness of the range of transport paths in the vadose zone are to be developed through consensus between DOE and its contractors and representatives of the regulatory, stakeholder, and Tribal Nation community. As a preamble to the criteria, the following list from CRCIA Part II document specific requirements related to the Vadose Zone technical element. CRCIA Part II –A.3 (Transport Mechanisms and Pathways to the Columbia River) discusses the transport requirements for assessing the transport of all Hanford-derived contaminants to the Columbia River via the vadose zone and groundwater pathways. CRCIA Part-B.2 (Model Integration and Consistency) discusses the overall assessment needs to conform to established laws and sound practices. From these sections key requirements are highlighted and described. Each item listed is connected to a CRCIA requirement as indicated.

1) Identify geologic features associated with all pathways in the vadose zone (A3.1-3).
2) Identify the transport mechanisms associated with each pathway (A3.1-5).
3) Identify hydraulic properties of the sediments within the vadose zone. This should be construed to include the unsaturated hydraulic conductivity (direct measure or reliable estimate), the water retention characteristics, porosity and related properties including the effects of salts and temperature on the hydraulic properties (A3.2-3).
4) Identify geochemical properties of sediments within the vadose zone. This includes changes in mobility induced by remediation and technical development and deployment, effects of chelating agents, such as EDTA, and other chemicals (A3.2-4).
5) Identify and assess the effects of net water infiltration from meteoric sources on contaminant migration rates (A3.3-1).
6) Identify and assess the effects of permitted discharges on vadose zone contaminant migration rates (A3.3-1).
7) Identify the impacts of unintentional releases (i.e., leaking water lines and similar discharges) on vadose-zone contaminant migration (A3.3-1).
8) Assess the effects of discharged chemicals on mobilization and consequent migration rates of contaminants in the Hanford Site vadose zone (A3.3-1).
9) Assess the migration of contaminants from the vadose zone through the capillary fringe to the water table (saturated groundwater) (A3.3-2).
10) Ensure that the migration of contaminants to soils immediately adjacent to containment packages is adequately represented, especially as saturated with escaped effluents (A3.3-2).
11) Ensure that the migration from vadose zone to groundwater is adequately represented (A3.3-2)
12) Ensure that the mixing of contaminant from vadose zone into groundwater is adequately represented (A3.3-2).
13) Ensure that mass and moment is conserved across any geographical partition of the vadose zone into sub-regions and into the water table (B2.2-1).
14) Ensure that mass and momentum is conserved at the interface between groundwater in the vadose zone and the saturated zone (B2.2-2)

*Physical pathways, chemicals/radionuclides, and the transport mechanisms that need to be modeled all play a role in development of the candidate and study sets. Development of candidate and study sets for the vadose zone transport pathway involves understanding the spatial and/or temporal nature (past, present, and future) of the Hanford sediment that lie above the capillary fringe of the unconfined and confined groundwater systems. This includes the interfaces between the land surface and the saturated zones of the water table. It includes both transient and stable perched water bodies that lie within the vadose zone. Pathways from the waste disposal areas to the river are defined by a combination of knowledge regarding geologic structure and the physical and chemical driving forces and processes (e.g., concentration gradients, reaction* *and adsorption rates) as they have developed to the present and are expected to evolve through time. It should be noted that these features are not independent, but inter-related. Important aspects of the system that must be developed and understood include the following.*

- *<u>Geohydrologic Structure and Characteristics</u>*
  *The geohydrologic structure and highly variable characteristics of the entire Hanford vadose zone, bounded in the upper extreme by the land surface where water entry is controlled, and at the lower extreme by the water table, delineating the underlying groundwater aquifer. In addition, it is also important to know location and characteristics of source areas of direct waste injection (i.e., bottoms of cribs, trenches, tanks or surface spills).*

- *<u>Hydrologic Boundary Conditions</u>*
  *Areal and vertical extent of the vadose zone pathway must be based on an understanding of the location and nature (e.g., temporal effects and variations) of any hydrologic boundary conditions affecting the pathway and the transport. These boundaries must be well understood since they limit areal and vertical extents of the vadose zone pathway(s) thus affecting predictions of waste migration from the land surface, or actual points near source area sites for radionuclides and chemicals of concern, to the river and other biosphere uptake points. Since the land surface boundary condition is highly variable, both spatially and temporally, for most waste sites these variation must be part of the conceptual and numerical models used for any realistic assessment of the contaminant transport.*

- *<u>Quantity, Properties, and Phases of Natural, Injected and Migrating Fluids</u>*
  *Natural driving forces associated with quantity (e.g., resulting from meteoric recharge interactions) and man induced forces associated with quantity (e.g., water use/pumping, irrigation, water line or hydrant leakage) must be considered since these can directly affect groundwater flow rates and directions of movement. Effects due to interactions between the geologic media and migrating waste fluids, directly injected wastes[1] (e.g., reverse wells), and waste fluids entering from the vadose zone must also be considered (e.g., precipitation and dissolution or other mechanisms that alter media properties). Properties of the injected fluid/fluids (e.g., density, viscosity, and waste media/water interactions) and the effect they have on migration rates and directions must be considered. Additionally, effects due to the phase of the waste and its solubility (e.g., DNAPL) must be considered as well as effects due to microbial interactions with wastes that take place in the vadose zone. Finally the affect that phase changes in the water (e.g., vapor phase which may be important near hot tanks and for hot fluids) and*

[1] <u>Wastes</u> – *Wastes as used above and in subsequent discussions of the groundwater transport pathways refer to chemicals and radionuclides of concern as well as other chemicals that could influence movement, chemical interactions, or the microbial interactions that take place in the groundwater system(s).*

*the effects related to the temperature (e.g., buoyancy, waste solubility, and changes in reaction rates) must be addressed.*

## Specific Criteria for Candidate Set

> CRCIA Part II – A.3 Transport Mechanisms and Pathways to the Columbia River (A3.1-3) Contaminant transport through the vadose zone to the Columbia River shall be assessed. A.3.1 Required Candidate Transport Paths Set. (A3.1-1) The Candidate Transport Paths Set shall be formed by identifying all potential paths for contaminant migration from existing and projected inventories to the Columbia River ( A3.3).

Vadose Zone transport pathway identification criteria follow:

**Geohydrologic System(s) –** Include the geohydrologic system(s) that could contain potential pathways for migration of Hanford wastes (e.g., the Hanford vadose zone, from land surface to the water table). Identify appropriate natural hydrologic boundaries and boundary conditions for these systems or other areal and vertical extent limiting boundaries and boundary conditions for these system(s) whose uncertainty does not significantly influence waste pathways through these systems.

**Waste and Fluid Entry/Exit Locations and Quantities –** Include the location and temporal variation in quantity for each known or suspected vadose zone entry or exit point for:

- recharge (both natural and as a result of man induced, e.g., gravel cover of tank farms),
- injected water (e.g., irrigation, pump and treat, disposal of process and other imported waters),
- wastes (e.g., leakage as a result of spills or tank ruptures transfer line losses, or direct discharge to cribs, trenches, ditches or ponds),
- withdrawn water (e.g., from perched water bodies),
- other fluids (sewerage discharges) and
- other sources from offsite, subsurface lateral spreading and any other sources that could influence vadose zone flow paths (velocity magnitude and direction) or location(s) of biosphere uptake through time.

**Geohydrologic Structure and Characteristics –** Consider the effect of geohydrologic system:

- structure (e.g., number of and character of the layers and their location and areal extent),
- the large scale geometry (e.g., slope and thickness of the layers, faults, folds; include clastic dikes as a vertical feature at most waste sites),
- small scale geometry/structure (e.g., cross-bedding), and
- spatial variability in the characteristics of these structures (e.g., layer thickness, small scale geometry/structure, other hydrologic, geochemical/mineralogical layer characteristics such as porosity, hydraulic conductivity, and buffering capacity) in determining potential pathways from

the waste entry areas to the vadose zone along potential past and suspected future vadose zone flow paths.

Physical and chemical interactions with the geohydrologic medium and geohydrologic structure must be considered in determining potential pathways. Potential effects of these interactions include:

- structure and characteristics alteration from interactions between the geologic media and migrating wastes (e.g., creating a high or low permeability zone as a result of dissolution or precipitation),
- alteration of waste mobility related to chemical interactions with the mineralogy of the geohydrologic system (e.g., the buffering capacity of the system alters the pH and/or REDOX potential and thus mobility or solubility), and
- structurally controlled direction and rate of waste movement dependent on the:
  - phase (e.g., DNAPLS migrate down dip of the structure) and
  - fluid properties (e.g., effect of density, viscosity, and wettability)

  of migrating wastes

**Waste and Fluid Properties –** Consider the affect that the properties of the injected fluids and waste can have in controlling the potential pathways and the geohydrologic system(s) of interest (e.g., sinking properties of DNAPLS could result in contamination of basalt aquifer). Considerations must include effects due to:

- the properties of the fluids (e.g., density, viscosity, wetting properties, phases, chemical properties, temperature), and
- other transporting media (e.g., colloids)

entering and exiting the vadose zone at the fluid and waste entry and exit locations discussed above. This is because the properties of the migrating fluids or other transporting media can alter the pathway followed (e.g., gravity forces associated with dense fluids, immiscibility of DNAPLS).
Additionally subsequent changes in the properties of these fluids upon entering and migrating through the vadose zone must be considered. This is because chemical and physical reactions can affect both soil and fluid properties and thus the likely paths, the controlling driving forces, and other flow and transport mechanisms that determine waste transport through the groundwater system(s).

**Processes/Mechanisms/Driving Forces. –** The controlling mechanisms, processes, and driving forces must be identified that:

- determine vadose zone transport pathways (e.g., advection, dispersion, density dependent flow),
- control degradation of wastes (e.g., decay, microbial degradation of nitrate or DNAPLS),
- alter mobility of waste chemicals (e.g., dissolution, precipitation, redox, pH),

- results in alteration of the physical or chemical characteristics of the geologic media thus affecting physical pathway, rates of migration, or fate of the migrating wastes.

Other mechanisms and driving forces such as heat that can affect physical (e.g., buoyancy) and chemical mechanisms (e.g., reaction rates) must also be considered in developing the vadose zone pathway analysis.

## Criteria for the Study Set which includes the Vadose Zone Element

> *CRCIA Part II – A subset of the corresponding candidate set that is to be used for the assessment analysis. Elements of the study set are to be represented explicitly in the assessment analysis. It is uniquely defined for one or more iterations of the assessment analysis.*

Each study set must be developed in terms of the defined need for the problem at hand. It is imperative that each study set must have a clearly stated and agreed upon purpose. The purpose of initial efforts is to allow development of a System Assessment Capability that supports a first-iteration demonstration or proof-of-principle assessment (using an agreed upon study set) by the end of Fiscal Year 2000. This initial effort will be part of the overall effort to develop a Groundwater Transport Paths Study Set (GWTPSS). Both the initial study set, and the study set for a more complete effort by end of FY 2003, must include those transport paths for radionuclides and chemicals that are important to the assessment of human and ecological health, socio-economic and cultural impacts. Demonstrating the appropriateness of the vadose zone model is also an important part of the effort.

### *Implicit Criteria*

Completing a first iteration of the System Assessment Capability and a demonstration system assessment in FY-2000 means initial study set selection must be completed quickly and thus the expressed desire for a fully comprehensive approach to initial study set selection can not be achieved in this first iteration. Therefore, the initial study set will be prepared in parallel with, and primarily in advance of, a the more complete effort scheduled for 2003, but the initial study set will be developed in a manner that is compatible with, and extensible to, the more comprehensive effort.

### *Explicit Criteria*

> *The criteria for selection of the vadose zone transport study set is based on the "Principles and General Requirements" outlined in CRCIA Part II (pages II-7 through II-12)". As discussed in this section of CRCIA, pathway and mechanism selection for inclusion in a study set is dependent on the "Preeminent Principles" of (Dominance, Uncertainty, and Fidelity) which requires an understanding of:*

- *which pathways and mechanisms are dominant,*
- *the uncertainty associated with describing these pathways and mechanisms, and*
- *the fidelity (i.e., temporal and spatial resolution) required to represent these dominant pathways and mechanisms as well as the resolution required to describe hot spots or resolve impacts at scales of concern.*

*Explicit criteria or steps in the selection of the vadose zone transport study set include:*

1) *Determine dominant pathways, geohydraulics, structure, and mechanisms based on:*
- *an examination of existing data and studies and*
- *sensitivity/screening analyses*
2) *Determine needed spatial and temporal resolution (i.e., fidelity requirements) for the vadose-zone pathway assessment in order to:*
- *assess impacts of concern related to direct use or interception of groundwater (e.g., irrigation or water supply well);*
- *match fidelity requirements/needs of the assessment modules interfacing with the vadose zone transport pathways (e.g., groundwater study set); and*
- *properly represent those pathways and mechanisms identified as dominant.*

*These steps should be integrated with other site efforts (e.g., the RPE, any EMSP or other Science and Technology Efforts and the Consolidated Groundwater Modeling project), and other parts of the SAC. The study set should make full use of existing data, knowledge/understanding and studies. The vadose zone study set will include a suite of knowledge based on the following criteria:*

Geologic features of the Hanford Site vadose zone must be understood and subsequently incorporated into the study sets per the requirement of dominance, variability, and fidelity. These features should include all layers and strata through which contaminants can migrate from the ground surface to the underlying water table. These layers and sequences include:

a) Hanford Formation Sands ---sand and gravel layers, facies and interspersed silt lenses
b) Hanford Formation Gravels---sand and gravel layers, facies and fine-grained lenses
c) Paleosols----cemented layers and caliche (carbonate rich sediments)
d) Ringold Formation-----variable sand, muds and gravels
e) Backfill -----mixture of one or more of the layer sequences in disturbed areas.
f) Clastic dikes---vertical geologic features through which drainage and migration might occur or lateral flow might be retarded.
g) Pedoturbation features---which exist in near surface and/or paleosols. These features reflect mixing of layer sequences by plant roots or animal burrowing and add to the uncertainties and complexity of the porous media that conducts the transport.

The key features should be identified and incorporated after screening tests are run to establish dominance of geologic features in controlling the flow for sites of interest.

All key boundary conditions that control unsaturated flow should be understood and incorporated into the study set per the requirements of dominance, uncertainty, and fidelity.  These boundary conditions include at the extremes, constant flux conditions (e.g., occurring during rainfall or liquid discharge input) and constant pressure head conditions (e.g., occurring during conditions of drying when head control dominates) at the land surface.  In general the surface is neither under constant flux nor constant (held) head conditions but is something dynamic in between.   At the water table the boundary conditions can also vary and range from unit gradient (steady gravity drainage) or held boundary conditions at the water table.  All hydrologic discontinuities and geologic features (e.g., clastic dikes, etc.) that affect lateral spreading and aid in accelerating flow should be considered in the candidate sets.   In addition, manmade features such as buried tanks, drums and pipes, including unsealed boreholes must be accounted for in the analysis since one or more of these features will impact the transport and travel times of contaminants to the water table.

Natural driving forces from meteoric sources and man-induced forces associated with water applications (e.g., irrigation, dust control, water line leakage, etc.) must be considered as key inputs, since these directly affect the travel time and transport rates and directions of contaminant plumes.  The following events can be considered part of the candidate date set for vadose zone transport from which a key study set can be derived.

a) large (millions of gallons) liquid discharges of neutralized fluids, such as exists at B pond, U pond, Gable Mtn. pond.
b) Liquid discharges of 1$^{st}$ cycle, 2$^{nd}$ cycle,, etc. tank wastes that have been either neutralized, or are acidic or basic.
c) Liquid discharges of uranium recovery wastes- acidifed vs. basic vs. neutralized.
d) Solid waste burial, old vs. new (stable vs. collapsed)  covered vs. barren.
e) Past tank leaks—volumes and distribution by tank farm
f) Future tank losses---leaks from SST and DSTs before and after pumping and sluicing
g) Sluicing losses-----leaks from sluicing lines and risers
h) Tanks Residues----potential losses from long-term leaching scenarios.

The study set will involve one or more of these liquid sources as inputs into the vadose zone.  Selection of which inputs will depend on the area represented in the study set and the information available about each of the dominant sources and how they are resolved in time and space.

The controlling mechanisms, processes, and driving forces must be identified for both water and chemical transport.  These processes must define the movement of fluids, and contaminants through the vadose zone pathway.

The candidate processes from which the study set processes are derived should include:

a) Standard Fickian diffusion
b) Isothermal processes
c) Non-isothermal processes
d) Steam flashing and gas venting
e) Advective gas transport
f) Barometric pumping

g) Simplified Linear isotherm (Kd) approach
h) Reactive chemical/coupled flow and transport
i) Altered mobility of chemicals by dissolution, precipitation, etc.
j) Gravity driven flow
k) Density dependent flow
l) Microbial or chemical degradation (nitrate, etc.)
m) Alteration of physical and chemical pathway from impacts of migrating wastes

Impacts that should be considered in the analysis should also include the dominant influences arising from :

- meteoric water inputs, including extreme events such as chinook wind-induced snowmelts
- water line leaks
- deliberate liquid discharges (irrigation, dust control , liquid discharge ponds and trenches adjacent to waste sites, etc).
- stratigraphic features including clastic dikes, sloping layered sediments (such as silt lenses and carbonate layer sequences).
- lateral (funnel) flow and unstable flow processes
- dissolution cavities developed beneath boiling tanks
- pore plugging developed by geochemical interactions of highly concentrated tank liquor onto Hanford sediments
- salinity and density effects on fluid transport
- thermal loads near tanks (heat pipe effects)
- vapor stripping by high salt solutions
- effects of water table fluctuations
- effects of barometric pumping phenomena
- surface changes such as wind and water erosion, plant intrusion
- fire (resulting in temporary loss of surface vegetation)
- drought (resulting in extended loss of vegetation)
- microbiological changes impacting geochemical controls on migration rates.

## Anticipated Scoping Studies

*Scoping studies are required to determine the single (or dominant suite of) conceptual model (s) that define a representative suite of vadose zone settings at Hanford.  These include the vadose zone beneath:*

- *solid waste burial ground and other dry disposal areas*
- *past practice liquid discharge sites (cribs, trenches, ponds, tank leaks, etc.)*
- *canyon facilities and tunnels*

*These conceptual models shall be created through (1) an evaluation to reveal dominant features, events, and processes, and (2) an evaluation to define the adequacy of the temporal and spatial resolution, and (3) an evaluation to ensure an appropriate representation of uncertainty.*

*Some of the effort to develop the vadose zone component of the SAC may be carried out as part of the Science and Technology component of the Integrated GW/VZ project. However, significant elements of this effort will be conducted by the core projects as they define and employ conceptual models of the vadose zone.*

*Three scoping studies are proposed that address critical issues of vadose zone transport.*

***Scoping Study 1. Perched Water and Clastic Dike Study.*** *This study would address the impacts of tank leak contamination as affected by perched water and clastic dikes. This study would utilize data from T-106, SX-109, or other tank leak sites, where coring data, coupled with gamma and neutron logging provide some measure of history matching for vadose zone transport. The input would include known tank leak volumes for each leak site, known or estimated leak inventories and chemistries, including known or estimated solution densities, and estimated variations in recharge rates prior to and since leakage has occurred. In addition, the geohydrologic features would include both low permeability zones (paleosols, etc.) and clastic dikes, assumed to be in proximity to the tank leak. Predictions of the distribution and concentrations of key contaminants, such as Cs-137, Sr-90, Tc-99, nitrates would be compared with measured distributions for the period over which data are available. The tests would be run with and without clastic dikes to show the influence of lateral and vertical spreading of the contaminant plume using appropriate numerical models.*

***Scoping Study 2. Vadose Zone Chemically Altered Pathway Study.*** *This study would address the impacts of chemically altered hydrologic properties resulting from interactions of hot brines with sediments. The physical alteration, pore plugging and potential creation of channels (piping) that cause preferred flow needs to be investigated. Laboratory studies show that the waste brine that leaks from some tanks can precipitate at relatively low temperatures (<100 C). This study would include know stratigraphic features, known inventory and chemistry, known leak volumes and assumed recharge rates. The impact of hydrologic property changes will be studied by lowering the estimated hydrologic conductivities as the salt solution comes in direct contact with the sediments. Preferred pathways based on known or estimated channel formation and dissolution rates will be simulated and the rates of transport calculated. Emphasis for this study will be on the Cs-137 distributions. The model simulations will be compared with the measured gamma distributions from cores and gamma logs. Profiles from T-106 will be used in the history matching tests for this study.*

***Scoping Study 3. Vadose Zone Thermal Effects Study.*** *This study would address the impacts of thermal loading on the transport of tank leaks to the water table. The study would focus on SX-115 where Cs-137 gamma data are* *available from cores, dry wells and laterals and thermal data and water content data are readily obtained. A nonisothermal model would be used to predict the impact of heat loading on water and Cs-137 transport. Known inventory, leak volumes and chemistries would be used as input into the model. Best estimates of thermal and hydrogeologic properties would be used based on analog sites where sediment data are available. The model would be as true as possible to the stratigraphic features of the site including layer sequences and slopes. The model would be run in isothermal and nonisothermal mode to evaluate the impact of the heat loading on recharge and contaminant transport. One of the less understood features of the tank farms is the impact of heat on meteoric water input. This study would provide a measure of this impact over the lifetime a known leaking tank.*

**APPENDIX C. GROUNDWATER**
**CR COLE, RJ SERNE**

# Criteria for the Groundwater Transport Paths Set (A3.1)

### WORKING RULES AND OBSERVATIONS

1. Statement of Inclusion: It is recognized that the development of candidate and study set criteria and parameters is iterative. As set members and parameters are identified that may have been left out of a given set, they will be added to the appropriate set and criteria modified, as necessary. Though the goal of developing a candidate set is to be complete, it is recognized that any list, by its nature of being a list, is not complete. The GW/VZ Project must balance the need for completeness with the need for the initial assessment.

2. Multiple Study Sets: It is recognized that the development of criteria for study sets will also be iterative and depend on information from other technical elements. The purpose of the study set must be clearly stated to allow its development. Information not known maybe assumed and sensitivity to these assumptions investigated. Multiple purposes will require multiple study sets. This candidate and study set are based on development of a defensible assessment of the Hanford Site's post closure cumulative effects due to radioactive materials and chemicals.

3. Documentation: Sources of information must be identified. Assumptions must be explicitly identified and defended. This is particularly important for items intentionally given low priority in the initial assessment.

4. Level of Explicitness: It is recognized that data will be lacking to fully document in detail:
   - all possible pathways
   - all the transport mechanisms acting along these pathways
   - all the physical and chemical characteristics affecting transport along these pathways.

   The spatial/temporal resolution requirements and effects of transport process simplifications will need to be investigated through sensitivity studies. The rational for simplifications and the selected spatial/temporal resolution need to be explicitly defined and rationale provided.

### BACKGROUND

Physical pathways, chemicals/radionuclides, and the transport mechanisms that need to be modeled all play a role in development of the candidate and study sets. Development of candidate and study sets for the groundwater transport pathway involves understanding the spatial and/or temporal nature (past, present, and future) of the Hanford unconfined and confined groundwater systems. This includes the interfaces between these systems as well as the interface with the vadose zone and any associated surface water bodies (e.g., rivers and lakes/ponds). Pathways from the waste disposal areas to the river are defined by a combination of the knowledge regarding geologic structure and the nature and location of physical and chemical driving forces and processes (e.g., concentration gradients, reaction and adsorption rates) as they have and are expected to evolve through time. It should be noted that these are not independent, but inter-related. Important aspects of the system that must be developed and understood include the following.

- *Geohydrologic Structure and Characteristics*
  The geohydrologic structure and characteristics of the Hanford unconfined and confined groundwater systems between the likely source areas of direct waste injection or vadose zone interfaces where waste might enter the system and the discharge areas along the river and other surface water bodies must be understood.
- *Hydrologic Boundary Conditions*
  Areal and vertical extent of the groundwater system(s) must be based on an understanding of the location and nature (e.g., temporal effects and variations) of any hydrologic boundary conditions affecting these groundwater systems. These boundaries must be well understood since they limit areal and vertical extents of the groundwater system(s) thus affecting predicted pathways for waste migration from vadose zone entry points, near source area sites for radionuclides and chemicals of concern, to the river and other biosphere uptake points..
- *Quantity, Properties, and Phases of Natural, Injected and Migrating Fluids*
  Natural driving forces associated with quantity (e.g., resulting from recharge and river interactions) and man induced forces associated with quantity (e.g., water use/pumping and irrigation) must be considered since these can directly affect groundwater flow rates and directions of movement. Effects due to interactions between the geologic media and migrating waste fluids, directly injected wastes[2] (e.g., reverse wells), and waste fluids entering from the vadose zone must also be considered (e.g., precipitation and dissolution or other mechanisms that alter media properties). Properties of the injected fluid/fluids (e.g., density, viscosity, and waste media/water interactions) and the effect they have on migration rates and directions must be considered. Additionally, effects due to the phase of the waste and its solubility (e.g., DNAPL) must be considered as well as effects due to microbial interactions with wastes that take place in the groundwater system(s). Finally the affect that phase changes in the water (e.g., vapor phase which may be important near hot tanks and for hot fluids) and the effects related to the temperature

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[2] Wastes – *Wastes as used above and in subsequent discussions of the groundwater transport pathways refer to chemicals and radionuclides of concern as well as other chemicals that could influence movement, chemical interactions, or the microbial interactions that take place in the groundwater system(s).*

(e.g., buoyancy, waste solubility, and changes in reaction rates) must be addressed.

## Criteria for Candidate Set

> *CRCIA Part II – A.3 Transport Mechanisms and Pathways to the Columbia River (A3.0-2) Contaminant transport through the groundwater to the Columbia River shall be assessed. A.3.1 Required Candidate Transport Paths Set. (A3.1-1) The Candidate Transport Paths Set shall be formed by identifying all potential paths for contaminant migration from existing and projected inventories to the Columbia River.*

Groundwater transport pathway identification criteria follow:

**Geohydrologic System(s)** – Include the geohydrologic system(s) that could contain potential pathways for migration of Hanford wastes (e.g., the Hanford unconfined aquifer and underlying system of basalt aquifers). Identify appropriate natural hydrologic boundaries and boundary conditions for these systems or other areal and vertical extent limiting boundaries and boundary conditions for these system(s) whose uncertainty does not significantly influence waste pathways through these systems.

**Waste and Fluid Entry/Exit Locations and Quantities** – Include the location and temporal variation in quantity for each known or suspected groundwater system entry or exit point for:

- wastes (e.g., direct injection through reverse wells or from vadose zone leakance as a result of spills, leaks or direct discharge to cribs, trenches, ditches or ponds),
- recharge (both natural and as a result of man induced, e.g., gravel cover of tank farms),
- injected water (e.g., pump and treat, disposal of process and other imported waters),
- withdrawn water,
- other fluids (sewerage discharges) and
- water interchange along boundaries and with aquifer systems not explicitly represented

that could influence groundwater flow paths (velocity magnitude and direction) or location(s) of biosphere uptake through time.

**Geohydrologic Structure and Characteristics** – Consider the effect of geohydrologic system:

- structure (e.g., number of and character of the layers and their location and areal extent),
- the large scale geometry (e.g., slope and thickness of the layers, faults, folds),
- small scale geometry/structure (e.g., cross-bedding), and
- spatial variability in the characteristics of these structures (e.g., layer thickness, small scale geometry/structure, other hydrologic,

geochemical/mineralogical layer characteristics such as porosity, hydraulic conductivity, and buffering capacity)

in determining potential pathways from the waste entry areas to the river along potential past and suspected future groundwater flow paths.

Physical and chemical interactions with the geohydrologic medium and geohydrologic structure must be considered in determining potential pathways. Potential effects of these interactions include:

- structure and characteristics alteration from interactions between the geologic media and migrating wastes (e.g., creating a high or low permeability zone as a result of dissolution or precipitation),
- alteration of waste mobility related to chemical interactions with the mineralogy of the geohydrologic system (e.g., the buffering capacity of the system alters the pH and/or REDOX potential and thus mobility or solubility), and
- structurally controlled direction and rate of waste movement dependent on the:
  - phase (e.g., DNAPLS migrate down dip of the structure) and
  - fluid properties (e.g., effect of density, viscosity, and wettability)

  of migrating wastes

**Waste and Fluid Properties** – Consider the affect that the properties of the injected fluids and waste can have in controlling the potential pathways and the geohydrologic system(s) of interest (e.g., sinking properties of DNAPLS could result in contamination of basalt aquifer). Considerations must include effects due to:

- the properties of the fluids (e.g., density, viscosity, wetting properties, phases, chemical properties, temperature), and
- other transporting media (e.g., colloids)

entering and exiting the groundwater system(s) at the fluid and waste entry and exit locations discussed above. This is because the properties of the migrating fluids or other transporting media can alter the pathway followed (e.g., gravity forces associated with dense fluids, imiscibility of DNAPLS).

Additionally subsequent changes in the properties of these fluids upon entering and migrating through the groundwater system must be considered. This is because chemical and physical reactions can affect both soil and fluid properties and thus the likely paths, the controlling driving forces, and other flow and transport mechanisms that determine waste transport through the groundwater system(s).

**Processes/Mechanisms/Driving Forces.** – The controlling mechanisms, processes, and driving forces must be identified that:

- determine groundwater transport pathways (e.g., advection, dispersion, density dependent flow),

- control degradation of wastes (e.g., decay, microbial degradation of nitrate or DNAPLS),
- alter mobility of waste chemicals (e.g., dissolution, precipitation, redox, pH),
- result in alteration of the physical or chemical characteristics of the geologic media thus affecting physical pathway, rates of migration, or fate of the migrating wastes.

Other mechanisms and driving forces such as heat that can affect physical (e.g., buoyancy) and chemical mechanisms (e.g., reaction rates) must also be considered in developing the groundwater transport pathways.

## Criteria for the Study Set

> *CRCIA Part II – A subset of the corresponding candidate set that is to be used for the assessment analysis. Elements of the study set are to be represented explicitly in the assessment analysis. It is uniquely defined for one or more iterations of the assessment analysis. An example is the Contaminants Study Set which is a subset of the Candidate Contaminants Set. Another example is the Inventory Study Set which is a subset of the Candidate Inventories.*

Each study set must be developed in terms of the defined need for the problem at hand. It is imperative that each study set must have a clearly stated and agreed upon purpose. The overall purpose of the System Assessment Capability effort is development of a defensible assessment of the Hanford Site's post closure cumulative effects due to released radioactive materials and chemicals by 2003. The purpose of initial efforts is to allow development of a System Assessment Capability that supports a first-iteration demonstration or proof-of-principle assessment by the end of Fiscal Year 2000. This initial effort will be part of the overall effort to develop a Groundwater Transport Paths Study Set (GWTPSS). Both the initial study set and the study set for the 2003 effort must include those transport paths for radionuclides and chemicals that are important to the assessment of human and ecological health, socio-economic and cultural impacts. Recognizing that demonstrating the appropriateness of the groundwater system model is also an important part of the effort any additional pathways necessary to help validate the groundwater pathway model(s) (i.e., demonstrate the appropriateness and applicability of the groundwater pathway model(s)) need to be included.

### *Implicit Criteria*

Completing a first iteration of the System Assessment Capability and a demonstration system assessment in FY-2000 means initial study set selection must be completed quickly and thus the expressed desire for a fully comprehensive approach to initial study set selection can not be achieved in this first iteration. Therefore, the initial study set will be prepared in parallel with, and primarily in advance of, a the more complete effort scheduled for 2003, but the initial study set will be developed in a manner that is compatible with, and extensible to, the more comprehensive effort.

### ***Explicit Criteria***

*The criteria for selection of the GWTPSS is based on the "Principles and General Requirements" outlined in CRCIA Part II (pages II-7 through II-12)". As discussed in this section of CRCIA, pathway and mechanism selection for inclusion in a study set is dependent on the "Preeminent Principles" of (Dominance, Uncertainty, and Fidelity) which requires an understanding of:*

- *which pathways and mechanisms are dominant,*
- *the uncertainty associated with describing these pathways and mechanisms, and*
- *the fidelity (i.e., temporal and spatial resolution) required to represent these dominant pathways and mechanisms as well as the resolution required to describe hot spots or resolve impacts at scales of concern.*

*Explicit criteria or steps in the selection of the GWTPSS include:*

3) *Determine dominant pathways and mechanisms based on:*
   - *an examination of existing data and studies and*
   - *a sensitivity/screening analysis(es)*
4) *Determine needed spatial and temporal resolution (i.e., fidelity requirements) for the groundwater transport pathway assessment in order to:*
   - *assess impacts of concern related to direct use or interception of groundwater (e.g., irrigation or water supply well);*
   - *match fidelity requirements/needs of the assessment modules interfacing with the groundwater transport pathways (e.g., river study set); and*
   - *properly represent those pathways and mechanisms identified as dominant.*
5) *Integrate with*
   - *other site efforts (e.g., the RPE, Consolidated Site-wide Groundwater Modeling effort and any EMSP or other Science and Technology Efforts), and*
   - *other parts of the SAC.*
6) *Make full use of existing data, knowledge/understanding and studies.*
7) *Clearly identify all the issues as well as assumptions and document the basis for all these assumptions.*

It is recognized that some iteration is required.

## Anticipated Scoping Studies

*Much of the effort for development of the groundwater portion of the SAC will be carried out as part of the Consolidated Sitewide Groundwater Modeling Program. The tables below illustrate the identified issues and concerns (Table 1) identified by the Sitewide Groundwater Modeling Program and as a result of the recent Peer Review group. A copy of the executive summary from the peer review group is given in Attachment 1 ("Report of the Peer Review Panel on the Proposed Hanford Site-Wide Groundwater Model" by Steven Gorelick, Charles Andrews, and James Mercer). The initial planning matrices being developed to address the identified technical issues and concerns are shown in the following tables:*

- *Sensitivity studies (Table 2),*
- *Model calibration and uncertainty activities (Table 3), and*
- *model implementation activities (Table 4)*

## Table 1. Technical Issues and Concerns (DRAFT)

| Technical Issues and Concerns | Recommendations Report | Peer Review Report |
|---|---|---|
| **NEEDS AND REQUIREMENTS** | | |
| ***Adequacy of Conceptual Model and Numerical Implementation*** | - | - *this or any general-use, site-wide model cannot be expected to be adequate for all potential uses. An initial task should be to specify a narrower, and perhaps more pragmatic, list of model uses that involve less disparate temporal and spatial scales and contaminants whose behavior can be adequately characterized by linear sorption and first-order decay.* |
| ***3 Source-Code Availability*** | - needs and requirements for the computer code used in the consolidated site-wide groundwater model identified the availability of the source code as an administrative requirement. Having the source code would enable the ability to make modifications to the source code, if the need arises, and to repeat analyses even if the code author(s) no longer supports the code. | - necessary requirement |
| ***Regulator/Stakeholder Involvement*** | - continual informal interaction during consolidation process<br>- need model/code access | |
| ***Reactive Transport*** | - questioned whether a capability to model interactions between chemical contaminants should be a requirement | - The existing representation of chemical reactions is limited to first-order decay and linear sorption.<br>- This representation is potentially adequate for some of the prevalent contaminants found in Hanford groundwater; however, for most of the contaminants of concern found in the vadose zone, reactive transport needs to be represented |
| ***Sub-Modeling Capability*** | | |
| ***Vadose Zone Interface*** | | |
| | | |
| **Proposed Site-Wide Groundwater Model** | | |
| ***Large-scale Heterogeneity*** | - only large scale features and differences in major hydrostratigraphic units captured<br>- | - The existing deterministic modeling effort has not acknowledged that the prescribed processes, physical features, initial and boundary conditions, system stresses, field data, and model parameter values are not known and cannot be known with certainty. Consequently, predictions of heads and concentrations in three dimensions over time will be uncertain as well.<br>- A new modeling framework must be established that accepts the inherent uncertainty in model conceptual representations, inputs, and outputs. Given such a framework, the expected values of heads and concentrations, as well as the range (distribution) of predictions, would be products of the site-wide groundwater model.<br>- A priority task is to construct a comprehensive list of alternate conceptual model components and to assess each of their potential impacts on predictive uncertainty.<br>- The domain covered by the site-wide groundwater model must be better justified.<br>- The unconfined aquifer to the north and east of the river and the bedrock |
| ***Uncertainty in Interpretation of Geometry of Major Hydrogeologic Units*** | - sufficiency of data to support refinement of Ringold into 3 sand and gravel units and three "mud" units<br>alternative conceptual model of muds (with possibility of sand stringers in muds) needs to be evaluated | |

| | | |
|---|---|---|
| ***Impact of Structural Geologic Controls*** | - fault north of Gable Mt and Gable Butte<br>- May Junction and Cold Creek Faults | |
| ***Uncertainty in Hydraulic Properties*** | - based on sparse set of data from hydraulic testing<br>- need sensitivity analysis over range of measured parameter<br>- concern about disaggregation of 2D T's to 3D K's. Other methods need to be evaluated<br>- concern over specific yield values for the Ringold sediments<br>- | |
| ***Uncertainty in Lateral Boundary Conditions*** | - Boundary fluxes at Cold Creek, Dry Creek, Rattlesnake springs based on current day conditions. These will likely change in future<br>- Concern on vertical distribution of fluxes and how applied | |
| ***Columbia River Boundary Conditions*** | - approach of using the centerline of the Columbia River as a line of symmetry given that the heads in the aquifer are so much greater on the Franklin County side.<br>- periods during which the actual relative river stages results in much different flow-system dynamics than those depicted by using median stages of the river.<br>- Consideration should be given to using head-dependent flux boundaries at the Columbia River (and Yakima River) rather than the specified-head boundaries | |
| ***Interaction with Basalt confined Aquifers*** | - potential for recharge to the unconfined aquifer from the upper confined aquifer should be investigated | |
| ***Uncertainty in Recharge*** | - The applicability of present-day estimates of recharge in long-term simulations<br>- The effect of macropore recharge has not been considered in current estimates of recharge<br>- evapotranspiration considered in the estimate of artificial recharge<br>- unclear how artificial recharge in the Richland area in the form of infiltration from ponds, agriculture and residential irrigation, and disposal of wastewater at the potato-processing plants has been handled. | |
| ***Model Discretization Issues*** | - Concerns were expressed about the oddly shaped elements used where the transport grid transitions from coarse to fine sediments | - Spatial variability of recharge should be treated geostatistically to determine expected values, spatial correlation, and estimated uncertainties.<br>- Need to develop a strategy to represent the spatial distribution of recharge for a range of climatic conditions, consequent vegetation, and antecedent soil |

| | | |
|---|---|---|
| | | moisture conditions. |
| ***Flow-Model Development and Calibration*** | - Because the model is calibrated to heads only (i.e., none of the significant inflows and outflows is measurable), modeling results will always contain significant uncertainty<br>- Calibration also focused on matching measured water-table elevations. Future work should consider examining vertical head data or information where it is available. | |
| ***Transport-Model Development and Implementation*** | - Data showing the vertical distribution of contaminants in the unconfined aquifer are generally lacking in most areas leading to uncertainty in defining initial conditions<br>- vertical discretization of most of the model area may be too coarse to accurately simulate the vertical migration of contaminants<br>- Data being used to calibrate the transport model may not be sufficient. Although there is adequate information on areal distributions of contaminants in 1985 and 1995, the differences between the distributions are not large.<br>- transport model (or a particle-tracking model) should be used to check simulated travel or first-arrival times against observed data<br>- Future simulations of existing plumes have assumed that no new contaminants will reach the aquifer in the future | - The calibration procedure for the current model is not defensible. Reasons include<br>- the insufficient justification for using a single snapshot of presumed steady-state conditions in 1979,<br>- over-parameterization of zonal transmissivities given an insufficient number of independent data,<br>- potential for incompatibility between pumping-test results and model representation of the aquifer,<br>- 2D model calibration for a 3D model, and use of interpolated head values. |

| | | |
|---|---|---|
| ***4 Code Selection*** | | **Dispersion:**<br>- The selection of dispersivity values based solely on model element sizes and the Peclet number criterion is problematic for the following reasons: 1) Any physical interpretation of dispersivity values is lost. 2) An empirical or theoretical relationship between dispersivity and travel distance scale is not used. 3) The resolution of the mesh dictates the dispersion of the plume.<br>- The transverse dispersivities are unlikely to be 1/5 of the longitudinal dispersivity for all scales of interest. Furthermore, vertical transverse dispersivity values are most likely smaller than the horizontal transverse dispersivity values.<br>- must be recognized that the concentrations produced by the SGM do not represent local values when using large field-scale dispersivities<br>**EFFECTIVE POROSITY**<br>- no physical justification to base effective porosity values on measured specific yield values.<br>- Effective porosity values must be estimated, and the impact of their uncertainties must be assessed<br>**STORAGE COEFFICIENT**<br>- The error introduced by using wrong storage coefficient values may be responsible for some predictive errors.<br>**DIFFUSIVE MASS TRANSFER**<br>- Tailing of contaminant plumes is likely to be significant in the unconfined aquifer at the Hanford site. Therefore, the SGM will overestimate the rate at which contaminant plumes migrate and dissipate after a source has been removed because diffusive mass-transfer to and from immobile domains is not considered.<br>- Recommends that diffusive mass-transfer be addressed by modifying CFEST-96 to permit the option of including a mobile-immobile domain formulation.<br>**Initial Concentration Conditions**<br>- The vertical extent of the contaminant plumes at the Hanford site is poorly defined, and as a result, the initial concentration conditions for contaminant transport simulations have a large uncertainty associated with them |
| ***Configuration Control and Management*** | | |

## Table 2. Sensitivity Analyses (DRAFT)

| Sensitivity Activity | Priority | Relative Level of Effort | Model Refinements & Modifications Task | Critical Issues Task | Future Tasks |
|---|---|---|---|---|---|
| | | | | | |
| **INFLOWS AND OUTFLOWS** | | | | | |
| - Cold Creek & Dry Creek Valleys | | | | | |
| - Rattlesnake Hills Springs | | | | | |
| - Yakima River | | | | | |
| - Columbia River | | | | | |
| - Natural Recharge | | | | | |
| **- Leakage to/from basalts** | | | | | |
| - Artificial recharge | | | | | |
| | | | | | |
| **OTHER HYDRAULIC ISSUES** | | | | | |
| - Uncertainty in flow through Gable Butte Gable Mountain region | | | | | |
| - Importance of Ringold Muds | | | | | |
| - Storage properties | | | | | |
| **- DISAGGREGATION FROM 2D T'S TO 3D K'S** | | | | | |
| - Impact of Flow from across the Columbia River | | | | | |
| | | | | | |
| **TRANSPORT ISSUES** | | | | | |
| - Dispersivity | | | | | |
| - Effective Porosity | | | | | |
| - Initial Concentration Conditions | | | | | |

## Table 3. Model Calibration/Uncertainty Activities (DRAFT)

| **Calibration/Uncertainty Activity** | **Priority** | **Model Refinements & Modifications Task** | **Critical Issues Task** | ***FY 2000*** | **FY2001** | ***5 FY 6 2002-04*** |
|---|---|---|---|---|---|---|
| | | | | | | |
| **RESPONSES TO PAST CALIBRATION PROCEDURE** | | | | | | |
| - Justification for 1979 as Steady State | | | | | | |
| - Overparameterization of T's | | | | | | |
| - 2D T's to 3D K's | | | | | | |
| | | | | | | |
| **POTENTIAL TRANSIENT RECALIBRATION** | | | | | | |
| - Assessment of Available Methods | | | | | | |
| - Assessment of 3D data availability | | | | | | |
| - Development of Strategy | | | | | | |
| - Implement Recalibration | | | | | | |
| - DOCUMENT RECALIBRATION | | | | | | |
| | | | | | | |
| **FRAMEWORK FOR UNCERTAINTY** | | | | | | |
| - Assessment of Available Methods | | | | | | |
| - Development of Strategy | | | | | | |
| - Implement Strategy | | | | | | |

## Table 4. Model Implementation (DRAFT)

| Model Implementation Activities | Priority | Recommendations Report | Model Refinements & Modifications | Model Maintenance | *FY 2000* | *FY-2001* | *FY 2002-04* |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| **WHITE PAPER ON CONSIDERATIONS IN APPLICATION OF SITE-WIDE MODEL** | | | | | | | |
| | | | | | | | |
| **CODE MODIFICATIONS/ENHANCEMENTS** | | | | | | | |
| - Dispersivity formulation | | | | | | | |
| - DIFFUSIVE MASS TRANSFER | | | | | | | |
| - OTHER ENHANCEMENTS | | | | | | | |
| | | | | | | | |
| **ONGOING CONFIGURATION CONTROL** | | | | | | | |
| - COMPUTER CODE | | | | | | | |
| - Databases and Information Bases | | | | | | | |
| | | | | | | | |
| **Code/Model Training Workshops** | | | | | | | |
| | | | | | | | |
| **ESTABLISH/IMPLEMENTATION OF SITE MODEL REVIEW GROUP** | | | | | | | |

### *Relationship to CRCIA Part II Requirements*

The relationship of the proposed Candidate Set criteria and initial Transport Pathways Study Set criteria are illustrated in the following table derived from CRCIA Part II Appendix II-A.

| CRCIA REQUIREMENTS | | INCORPORATED IN CRITERIA? |
|---|---|---|
| | | |
| A.3 Transport Mechanisms and Pathways to the Columbia River | | |
| | | |
| (A3.0-3) | Transport characteristics of geologic formations, such as the Hanford formation and Ringold formation, shall be established to the degree needed to support the assessment. | Yes, Incorporated into the criteria |
| (A3.0-5) | Migration rates to and concentrations in the Columbia River of all contaminants shall be determined, including estimates of holdup periods in travel time calculations. | Yes, Incorporated into the criteria |
| (A3.0-6) | Chemical forms and physical characteristics of radionuclides, such as solubility and sorption rates, shall be considered to the extent that migration rates are affected. This consideration shall include probable modifications of the original contaminants' characteristics as contact is made with soils, groundwater chemistry, and other contaminants. | Yes, Incorporated into the criteria |
| (A3.0-7) | Decay of radionuclides during transport shall be evaluated. | Yes, Incorporated into the criteria |
| A.3.1 Required Candidate Transport Paths Set | | |
| (A3.1-1) | The Candidate Transport Paths Set shall be formed by identifying all potential paths for contaminant migration from existing and projected inventories to the Columbia river. | Yes, Incorporated into the criteria |
| (A3.1-2) | Criteria for determining the completeness of the range of transport paths to be included in the Candidate Transport Paths Set shall be established in consultation with the System Assessment Capability Team and shall be subject to its approval. | Yes, In progress |
| (A3.1-3) | Geologic features associated with each path shall be identified. An example is an aquifer. | Yes, Incorporated into the criteria |
| (A3.1-4) | Both confined and unconfined aquifers shall be included in the Candidate Transport Paths Set. | Yes, Incorporated into the criteria |
| (A3.1-5) | Transport mechanisms associated with each path shall be identified. | Yes, Incorporated into the criteria |
| A.3.2 Hydrogeologic Characterization | | |
| (A3.2-1) | Stratigraphy, including thickness, lateral extent, continuity of units, and pathways, shall be established. | Yes, Incorporated into the criteria |
| (A3.2-2) | The effect of geochemistry on migration rates shall be identified. An example is the retardation of the rate of contaminant migration. | Yes, Incorporated into the criteria |
| (A3.2-3) | Hydraulic conductivity, storage coefficient, and effective porosity shall be established. | Yes, Incorporated into the criteria |
| (A3.2-4) | Geochemical characterization shall include identifying the following: | Yes, Incorporated into the criteria |
| | a. changes in mobility brought about by remediation and technical development | |
| | b. the effects of chelating agents, such as EDTA | |
| | c.the long-term effects of chemicals introduced in connection with or as a part of remediation. An example is sodium dithionate weathering in contact with groundwater whose pH and dissolved oxygen change. | |
| A.3.4 Contaminant Migration in Groundwater | | |
| (A3.4-1) | Contaminant migration rates in groundwater from its source at the interface with the vadose zone to the river shall be identified. | Yes, Incorporated into the criteria |
| (A3.4-2) | Interaction between confined and unconfined aquifers and contamination transport shall be identified. | Yes, Incorporated into the criteria |

# ATTACHMENT 1

Executive Summary from:
"Report of the Peer Review Panel on the Proposed Hanford Site-Wide Groundwater Model"
by Steven Gorelick, Charles Andrews, and James Mercer

# Executive Summary

External peer review of the Proposed Hanford Site-Wide Groundwater Model was conducted in the Fall of 1998. The three-member review panel commented on three specific issues: 1) adequacy of the conceptual model and its technical capabilities to meet the anticipated uses and needs, 2) possible improvements to the modeling framework / implementation, and 3) immediate new data needs.

The Panel unanimously agreed that:

1) *The concept of developing a broadly applicable site-wide groundwater model is excellent. Scientists working for the U.S. Department of Energy–Richland Operations Office have made significant progress and should be commended for their superior efforts in dealing with voluminous data and complex field conditions, and for their integrated/interdisciplinary approach to model building.*

2) *With regard to the issue of model adequacy, the spectrum of anticipated uses and needs is so broad, ranging from time scales of less than 1 day to thousands of years and spatial scales of meters to kilometers, that this or any general-use, site-wide model cannot be expected to be adequate for all potential uses. An initial task should be to specify a narrower, and perhaps more pragmatic, list of model uses that involve less disparate temporal and spatial scales and contaminants whose behavior can be adequately characterized by linear sorption and first-order decay.*

3) *With regard to improvements in the modeling framework:*

   - The existing deterministic modeling effort has not acknowledged that the prescribed processes, physical features, initial and boundary conditions, system stresses, field data, and model parameter values are not known and cannot be known with certainty. Consequently, predictions of heads and concentrations in three dimensions over time will be uncertain as well.

   - A new modeling framework must be established that accepts the inherent uncertainty in model conceptual representations, inputs, and outputs. Given such a framework, the expected values of heads and concentrations, as well as the range (distribution) of predictions, would be products of the site-wide groundwater model.

   - A priority task is to construct a comprehensive list of alternate conceptual model components and to assess each of their potential impacts on predictive uncertainty.

   - Assessment can be initiated with hypothesis testing and sensitivity analysis within the general framework already established with the existing site-wide model. If uncertainties due to alternate conceptual models are significant, then a Monte Carlo analysis is required to estimate both the expected value of the prediction and its uncertainty.

4) *With regard to improvements in model implementation:*

   The Panel has identified a series of important improvements to the current site-wide modeling effort. A few of the most significant ones are listed below.

   - The calibration procedure for the current model is not defensible. Reasons include the insufficient justification for using a single snapshot of presumed steady-state conditions in 1979, over-parameterization of zonal transmissivities given an insufficient number of independent data, potential for incompatibility between pumping-test results and model representation of the aquifer, 2D model calibration for a 3D model, and use of interpolated head values.

   - The existing representation of chemical reactions is limited to first-order decay and linear sorption. This representation is potentially adequate for some of the prevalent contaminants found in Hanford groundwater; however, for most of the contaminants of concern found in the vadose zone, reactive transport needs to be represented. The decision that must be made at this stage is whether or not the umbrella of the site-wide groundwater model should cover reactive transport simulation or whether chemical processes are better handled by specialized local models. If the decision is to delegate chemical processes to specialized local models, it still may be possible to use hydraulic boundary condition values from the hydraulic component of the site-wide model. If the decision is to include reactive chemistry in the site-wide model, then the simulation framework must be based on a flexible open architecture that embraces complexities such as transport of multiple species, microbial degradation, and perhaps nonlinear feedback to the flow model as aquifer or water properties change.

   - The domain covered by the site-wide groundwater model must be better justified. The site-wide groundwater model simulates groundwater flow and contaminant transport only in the unconfined sedimentary aquifer in the Pasco Basin south and west of the Columbia River. The unconfined aquifer to the north and east of the river and the bedrock basalt aquifer are not represented in the site-wide groundwater model even though the major discharge area for both aquifers is the region adjacent to the Columbia River.

   - Boundary conditions and boundary fluxes should be re-inspected because of some inconsistencies with existing information and because of an insufficient conceptual basis for use of these conditions for applications of the site-wide model at both large and small scales.

   - Spatial variability of recharge should be treated geostatistically to determine expected values, spatial correlation, and estimated uncertainties.

5) *With regard to collection of new data:*

   - *The Panel believes that it is premature to initiate a campaign to collect new data. The highest priority is to adopt a broader modeling framework that accepts conceptual model uncertainty. Within this new framework the site-wide model would serve as an important tool to help guide new data collection efforts. First,* *the degree of likely impacts of the various sources of uncertainty can be assessed through analysis of all uncertainties including those introduced by alternate conceptual models. Second, the worth of new data for reducing costs and risks can be evaluated. Only then can the issue of additional data collection be logically addressed.*

- *The integration of the site-wide model with a geographic information system (GIS) is an excellent means to preserve the site data for applications at a variety of spatial scales. The Panel recommends that both* data-bases *(original field measurements) and* information-bases *(interpretations or interpolations) be maintained. For example, details in well logs found in the data-base could be used to develop a geostatistical model for scales smaller than that found in the interpreted hydrogeologic facies information-base.*

- *The Panel recommends that the site-wide groundwater model be thought of as a flexible and evolving platform for analyzing groundwater flow and contaminant transport. The model itself must not be stagnant because, as more data are collected, it is likely that the conceptual model of the groundwater system will change. In addition, new predictive capabilities undoubtedly will be desired. The adopted model framework must be one in which new concepts can be tested and enhancements readily included. It must have the capability of being modified to test alternative conceptual models, reflect the most recent consensus conceptual model, and address differing concerns regarding water resources and water quality.*

# 6 SYSTEM ASSESSMENT CAPABILITY

## Columbia River Technical Element

## Candidate and Study Sets

## RIVER ENTRY LOCATIONS

### 7 INITIAL CANDIDATE RIVER ENTRY LOCATIONS SET

The Candidate River Entry Locations Set will identify those locations at which contaminants enter the Columbia River environment. Contaminants enter the Columbia River via multiple pathways. Contaminants from Hanford Site sources, as well as from non-Hanford sources, enter the river via these pathways. The Candidate River Entry Locations Set links the Vadose Zone, Groundwater, Atmospheric, and Biological Contaminant Transport Paths to the River.

> CRCIA Part II – "The Candidate Transport Paths Set shall be formed by identifying all potential paths for contaminant migration from existing and projected inventories to the Columbia River"
>
> CRCIA Part II – "The Candidate River Entry Location Set shall be formed by identifying all potential river entry locations"

Criteria to determine the initial Candidate River Entry Locations Set include:

- Groundwater discharge from the aquifers on either side of the river
- Suspended load brought to the Reach from upstream and local sources
- Surface water runoff, including natural runoff, irrigation water returns, and other waste water
- Resuspension of contaminants stored in riverbed sediment
- Fallout from the atmosphere onto the Reach
- Transport via biological processes

### *Preliminary Candidate River Entry Locations Set*

- Groundwater discharge points throughout study area, both sides of river
- Columbia River upstream in area unaffected by Hanford operations
- Surface water discharge points along entire study area
- Areas of current sediment accumulation (see River Holdup Locations)
- Others to be determined

Anticipated scoping studies to determine initial Candidate River Entry Locations Set

Several scoping studies are proposed to provide baseline data and improved conceptual understanding of contaminant entry. The results of these scoping studies will be used to refine the proposed candidate set and subsequent study sets. Scoping studies are also intended to provide results that are applicable to near-term environmental restoration decisions, such as interim remedial actions. Of the potential pathways for Hanford-derived contamination to enter the Hanford Reach, the groundwater pathway is likely to be the most significant under current and near-future conditions.

An accurate description of the ***spatial relationship between the contaminated aquifer and the river channel*** is fundamental to estimating where and at what rates contamination is entering the Reach from the Hanford Site. This scoping study would use existing geologic information from well logs and channel bathymetric data. Cross sections through each of the contaminant plumes that are currently entering the river via groundwater movement would be prepared. The approximate area of the river bottom where contaminated groundwater is likely to be upwelling into the river would be defined on maps.

Recently-installed aquifer sampling tubes provide an unprecedented opportunity for observational data on water quality at locations very close to points of discharge into the river. Further analysis of existing data and continued monitoring of the water quality in these tubes will provide much needed insight on ***processes that occur in the zone of interaction between groundwater and river water***. Of immediate interest for regulatory decisions is the degree of natural attenuation that may be occurring within the interaction zone.

## INITIAL RIVER ENTRY LOCATIONS STUDY SET

The River Entry Locations Study Set is defined to be a subset of the corresponding Candidate Set that is to be used for the assessment analysis. Elements of the River Entry Locations Study Set will be clearly defined in the assessment. The study set is uniquely defined for each iteration of the assessment. As is the case with the Candidate River Entry Locations Set, the River Entry Locations Study Set will be dependent to some degree on, and consistent with the Contaminant Study Set.

> CRCIA Part II – A subset of the Candidate River Entry Locations Set; the set of river entry locations to be used for a given assessment iteration

### ***Criteria to determine initial River Entry Locations Study Set***

- Candidate River Entry Locations verified to include Hanford-origin contaminants identified in the Contaminant Study Set

### ***Anticipated scoping studies to determine initial River Entry Locations Study Set***

Groundwater entering either side of the Hanford Reach shall be characterized to describe the geometry of the interface between the river channel and aquifer; the water quality of the discharging groundwater; the rate of discharge; and the mass flux of contaminants. Principal products include maps showing the locations where contaminant plumes enter the river; cross sections showing the geometric relationship between the river channel and aquifers, and a database containing the results of water analyses from sampling sites near the river/aquifer interface.

The suspended load of Columbia River water shall be characterized as it approaches the Hanford Site after being discharged from the Priest Rapids Dam. The mass and composition of the suspended load shall be characterized, and the seasonal variability determined, at locations upstream, within, and downstream of the Hanford Site. The contribution to the suspended load from Hanford Reach sources shall also be characterized—e.g., from land sliding and human activities. Principal products include maps and cross sections that show the distribution and composition of the suspended load; areas within the Reach where sediment is being added to the river; and a database containing the results of sample analyses.

Contaminant input to the Hanford Reach from surface sources shall be identified and characterized with respect to its volume, water quality, and temporal variability. Locations of irrigation waste water return and other waste-water return from human activities shall be inventoried, along with locations where natural precipitation may accumulate and discharge to the Reach. Principal products include maps and databases.

The erosion and deposition pattern within the Hanford Reach shall be described using bathymetric data, sediment grain-size distributions, the flow pattern of the river, and hydraulic models. The locations of structures formerly used to discharge liquid wastes shall be described relative to the erosion/deposition pattern of the river. Former facilities include outfall pipes that extend from the reactor areas to the channel center, and outfall flumes (concrete structures) at the shoreline of each reactor area.

# RIVER HOLDUP LOCATIONS

## INITIAL CANDIDATE RIVER HOLDUP LOCATIONS SET

The Candidate River Holdup Location Set will identify regions in the river environment that serve as a source of contaminants that may have the potential to impact humans, biota, or cultures. While locations of contaminant accumulation can be identified to some degree independent of the contaminants themselves, clearly in some cases the locations identified will be dependent on the physical and chemical properties of the specific contaminants of interest.

> *CRCIA Part II – the set of regions in the river where potential exists to accumulate inventories of harmful chemicals and/or radionuclides; that is, where contaminant transport downstream is retarded relative to the flow of water.*

Criteria to determine the Candidate River Holdup Location Set include:

- Those locations where contaminants/sediments accumulate or are determined to have the potential to accumulate in the river environment through the use of fate and transport models (basic hydrologic and sediment transport) and field observations.
- Those locations where contaminants are determined to have the potential to accumulate outside of the immediate river environment as a result of water withdrawal, treatment, and/or redistribution.
- Contaminant holdup within the biological system will be defined and accounted for through the food web, biological transport models, and exposure models.

### *Anticipated studies/capabilities to determine initial Candidate River Holdup Location Set*

In order to determine the Candidate River Holdup Locations, the development of modeling capabilities and field studies will be necessary. Fate and transport models (hydrodynamic, sediment, contaminant, and biological) will be used to identify areas within the river where sediment/contaminants may accumulate. River bathymetric information will be necessary to develop such modeling capabilities. In addition, some field verification of sediment accumulation and contaminant concentrations will be needed to confirm that the representativeness of the models. Locations of water withdrawal for uses with the potential to accumulate water-borne contaminants in areas away from the river must be identified and mapped as well.

<u>Preliminary Candidate River Holdup Location Set:</u>

- Behind downstream impoundments within the study area
- Sloughs
- Downstream of islands
- Inside shoreline of bends in the river
- Deep holes
- Along shorelines, particularly immediately downstream of points projecting out into river
- Downstream of large submerged structures – ie, outfall structures, boulders, etc.
- Biological contaminant sinks
- Water withdrawal intake structures
- Sanitary water treatment plant sludge deposition areas
- Sanitary water system reservoirs, ponds, etc.
- Long-term irrigation application areas

## INITIAL RIVER HOLDUP LOCATION STUDY SET

The River Holdup Location Study Set is defined to be a subset of the corresponding Candidate Set that is to be used for the assessment analysis. Elements of the River Holdup Location Study Set will be clearly defined in the assessment. The study set is uniquely defined for each iteration of the assessment. As is the case for the Candidate River Holdup Locations Set, the River Holdup Locations Study Set will be dependent to some degree on, and consistent with the Contaminant Study Set.

> *CRCIA Part II – A subset of the Candidate River Holdup Location Set; the set of river holdup locations to be used for a given assessment iteration.*

Criteria to determine the initial River Holdup Location Study Set include:

- Candidate river holdup locations verified to be areas of sediment and Hanford-origin contaminant accumulation
- Areas of sediment/contaminant accumulation that coincide with sensitive habitat and/or critical locations as defined through the Candidate Habitat Location Set and Critical Habitat and Uptake Locations Study Set for the corresponding assessment iteration.

### *Anticipated scoping study to determine River Holdup Locations Study Set*

In order to narrow the Candidate River Holdup Locations Set to the River Holdup Locations Study Set, some field studies will likely be necessary to collect and document the information necessary to apply the criteria to determine the study set. Existing data will be used to the extent possible and appropriate for determining the River Holdup

Locations Study Set. Field activities will include the visual confirmation of the presence of sediment accumulation in areas identified in the Candidate River Holdup Locations Set and, at those locations where adequate sediment accumulation has occurred, the collection and analysis of sediment samples such that the presence of Hanford-origin contaminants can be verified. The verification of the presence of Hanford-origin contaminants requires that the background concentrations of the contaminants of interest be known. Additional characterization studies will likely be necessary to provide this information. In this manner, the Hanford contribution to the contaminant load will be determined, allowing for the determination of the potential risk/impacts/consequences to the riverine environment attributable to Hanford.

## HABITAT AND UPTAKE LOCATIONS

### *INITIAL CANDIDATE HABITAT AND UPTAKE LOCATIONS SET*

The Candidate Habitat and Uptake Locations Set defines the important locations of plant and animal habitat, for both aquatic and river-dependent terrestrial life, where uptake of contaminants is probable. This set includes sensitive habitat and critical locations. Sensitive habitat includes that which is defined to be by the state, habitat that is has been determined to be rare or unique to the study area, and habitat that is essential for the Candidate Receptors Set and Receptors Study Set. Critical locations are defined as those places where the entry of contaminants into the food chain and other exposure pathways are most likely to occur. The Candidate Habitat Location Set and subsequent development of the Habitat Location Study Set links the areas of contaminant accumulation to the biological, social, economic, and cultural dependency webs defined in the Risk Technical Element.

> *CRCIA Part II – The set of habitat regions that potentially are sites for contact between harmful chemicals or radionuclides and biota.*

Criteria to determine the Candidate Habitat Location Set include:

- Regulatory defined sensitive habitat (wetlands protection, Endangered Species Act, etc.)
- Habitat critical to Candidate Receptor Set (human, biota, cultural, socio-economic)
- Habitat on critical pathway of dependency web for Candidate Receptor Set
- Rare habitat
- Habitat unique to the study area
- Decreasing availability
- Point of introduction into exposure pathway

### *Preliminary Candidate Habitat and Uptake Locations Set*

- Salmon spawning
- Steelhead
- Sensitive cultural sites
- Drinking water withdrawal points
- Recreational use areas
- Others to be determined

Anticipated scoping studies to determine initial Candidate Habitat and Uptake Locations Set

*In order to determine the Candidate Habitat and Uptake Locations Set, the study area must be characterized in terms of the existing habitat present and river use. Maps or GIS layers will be generated identifying habitat types and river use locations. This information, used in conjunction with dependency webs as defined through the Risk Technical Element, will be used in determining the Candidate Habitat and Uptake Locations Set.*

## INITIAL CRITICAL HABITAT AND UPTAKE LOCATIONS STUDY SET

The Critical Habitat and Uptake Locations Study Set is defined to be a subset of the corresponding Candidate Habitat and Uptake Location Set that is to be used for the assessment analysis. Elements of the Habitat Location Study Set will be clearly defined in the assessment. The study set is uniquely defined for each iteration of the assessment. As is the case for the Candidate Habitat Locations Set, the Critical Habitat and Uptake Locations Study Set will be dependent to some degree on, and consistent with the Receptor Study Set.

> *CRCIA Part II – The Critical Habitat and Uptake Location Study Set is a subset of the Candidate Habitat Location Set; the set of habitat and uptake locations to be used in a given assessment iteration*

Criteria to determine the initial Critical Habitat and Uptake Locations Study Set include:

- Coincides with River Entry Locations Study Set
- Coincides with River Holdup Locations Study Set
- Essential component within critical dependency web (biotic, human, cultural, etc.)
- Presence of Hanford-origin - known and/or demonstrated

Anticipated scoping studies to determine initial Critical Habitat and Uptake Locations Study Set

In order to narrow the Candidate Habitat and Uptake Locations Set to the Critical Habitat and Uptake Locations Study Set, scoping studies will be necessary to collect and document the information necessary to apply the criteria to determine the study set. One scoping study will include the evaluation of existing data and collection and analysis of environmental samples (as needed depending on availability of existing data) from the candidate locations such that the presence of Hanford-origin contaminants can be verified. Maps or GIS layers will be generated identifying areas of Hanford-origin contaminants that will be used in conjunction with habitat and river use maps/GIS layers to determine the Critical Habitat and Uptake Locations Study Set.

In addition to a scoping study, there will be a need to identify those locations that are included in the River Holdup Locations Study Set AND the Candidate Habitat and Uptake Locations Set through a direct comparison of the locations identified in the respective lists. Similarly, there will be a need to identify those items that are included in the Candidate Habitat and Uptake Locations Set AND identified as an essential/critical/sensitive component of a dependency web (human, biotic, cultural, etc) as defined through the Risk Technical Element. It is anticipated that maps and/or GIS layers will be the mechanism through which these concurrent locations will be determined.

**APPENDIX E. ATMOSPHERE**
**BA NAPIER, JV RAMSDELL JR**

# CRITERIA FOR ATMOSPHERIC TRANSPORT PATHWAYS (CRCIA A3.1, A3.6)

### *WORKING RULES AND OBSERVATIONS*

1. Statement of Inclusion: It is recognized that the development of candidate and study set criteria and parameters is iterative. As parameters are identified that may have been left out of a given set, they will be added to the appropriate set and criteria modified, as necessary. Though the goal of developing a candidate set is to be complete, it is recognized that any list, by its nature of being a list, is not complete. The GW/VZ Project must balance the need for completeness with the need for the initial assessment.

2. Multiple Study Sets: It is recognized that the development of criteria for study sets will also be iterative and depend on information from other technical elements. The purpose of the study set must be clearly stated to allow its development. Multiple purposes will require multiple study sets.

3. Documentation: All sources of information must be identified. Any assumptions must be explicitly identified and defended. This is particularly important for items intentionally given low priority in the initial assessment.

4. Level of Explicitness: It is recognized that data will be lacking for many possible contaminants at many waste sites. It is acceptable for some aggregation of waste site types, either in space, by source, or other common category. Any aggregations will be explicitly defined and rational provided.

## Criteria for the Atmospheric Transport Paths Candidate Set

> *CRCIA Part II – The set that identifies the paths and associated…features that potentially contribute to contaminant migration to the Columbia River.*

1. Atmospheric transport from the following types of Hanford sources of materials will be included:

- ***Active Atmospheric Release Sources*** Any Hanford site or facility planned to be actively discharging radioactive or hazardous chemical materials to the air will be considered (e.g., facilities with long-term planned air flow).
- ***Passive Atmospheric Release Sources*** Any Hanford waste disposal site that is anticipated to release materials to the atmosphere (e.g., tank ventilation systems, carbon dioxide/methane releases from decomposing wastes) will be considered.
- ***Wind-driven Atmospheric Release Sources*** Any Hanford site that is anticipated to have surface contamination other than natural and fallout-

derived background levels that could be resuspended by winds will be considered.

2 The types of materials that will included in transport models include gases, vapors, and particulates.

3 Processes of wet and dry deposition to soils, decay and weathering, and runoff into surface water will be included.

## Criteria for the Initial Atmospheric Pathway Study Set

> *CRCIA Part II – A subset of the corresponding candidate set that is to be used for the assessment analysis. Elements of the study set are to be represented explicitly in the assessment analysis. It is uniquely defined for one or more iterations of the assessment analysis*

Study sets are defined for use in the problem at hand. The purpose of the study set must be clearly stated and agreed upon. The overall purpose of the System Assessment Capability efforts is to perform a cumulative assessment of Hanford impacts. The purpose of the initial atmospheric transport study set is to allow development of the System Assessment Capability and support a first-iteration demonstration (proof-of-principle) assessment by the end of Fiscal Year 2000.

Depending on the purposes of future assessments, differing pathways from the candidate atmospheric transport set could be selected in future iterations.

The purpose of the initial Atmospheric Transport Pathway Study Set results in some implicit criteria as well as the more-formally defined explicit criteria. Supporting the concept of documentation of assumptions, these are listed below.

### *Implicit Criteria*

The intent to complete a first iteration of the System Assessment Capability and a demonstration system assessment indicates that the selection of the initial Atmospheric Transport Pathways Study Set must be completed within a period of a few months. This implies a limited ability to meet the necessity to be comprehensive; it will not be possible to fully evaluate all proposed Hanford operations and releases in this limited time. Therefore, the initial study set will be prepared in parallel with, and primarily in advance of, a more complete effort.

The initial Transport Study Set must use relatively readily-available data sources.

The process for developing the initial study set must be compatible with, and extensible to, the larger effort.

### *Explicit Criteria*

The approach involves a screening assessment that:

1) identifies a performance indicator (like risk),
2) conducts a screening analysis, and
3) selects those pathways comprising more than 1% of the indicator (in accordance with the concept of dominance), over the threshold value.

The performance indicator falls into the category of incremental radionuclide and chemical contaminant risk.

#### *7 1 Climatic Conditions*

The transport through the atmosphere will be based on current climatic conditions.

#### 2 Environmental Contamination

Because it is likely that current activities of waste processing, soil remediation, etc., are causing active releases that should be higher than any future passive releases, environmental conditions may be approximated with current atmospheric monitoring data.

#### 3 Exposure Pathways

Individual exposure via air submersion, inhalation, soil contamination, and ingestion of food products contaminated via foliar deposition, root uptake, and transport to animal products will be considered. In addition, an attempt will be made to relate offsite releases to runoff to the Columbia River, with the concomitant pathways of drinking, recreation, and aquatic foods.

#### 4 Risk Cutoff

The pathways associated with atmospheric transport will be considered in the initial assessment if lifetime risks to individuals along the Columbia River or at the river within the current Hanford Site from atmospheric releases are projected to be greater than one in one million for each pathway/contaminant combination.

## Anticipated Scoping Studies

The implementation of criteria defined above for selecting the initial Atmospheric Transport Pathways Study Set from the Candidate Set requires a scoping study. This scoping study is needed to develop the screening method and collect and document the supporting information.

A screening analysis will consider the potential for atmospheric transport to contribute to radiation dose and chemical contaminant risk. Inventories considered will be taken from the Inventories Study Set. Radionuclide risk will be considered using Federal Guidance Report 13 risk factors, and chemical risk will be considered using EPA cancer potency factors for carcinogens and reference doses for non-cancer risks. The scoping study will consider current Hanford emissions and pathways, as reported in recent Site Annual Reports (e.g. Dirkes and Hanf 1998), the pathways and techniques of the EPA-required reporting for the Clean Air Act (Gleckler and Rhoads 1998), and evaluation of current monitoring results for evidence of contaminant runoff into the Columbia River. The study will determine if any atmospheric pathways could be anticipated to result in risks in excess of one in one million to individuals living along the Columbia River.

Assuming approval to initiate work on the scoping studies in late February, the initial Atmospheric Pathways Study Set will be presented for review in April 1999. Approximately 1 person-week of effort is anticipated. The primary executor of the work will be PNNL, but staff of other Hanford contractors will be requested to participate at a low level of effort.

## Relationship to CRCIA Part II Requirements

The relationship of the proposed Candidate Set criteria and initial Transport Pathways Study Set criteria are illustrated in the following table derived from CRCIA Part II Appendix II-A.

| A.3 Transport Mechanisms and Pathways to the Columbia River | | |
|---|---|---|
| (A3.0-4) | All other paths of Hanford-derived contaminants to the Columbia River shall be considered. This shall include but not be limited to atmospheric transport, direct discharges, and transport of contaminants to the Columbia River by humans, either via personal contamination or intentional transport of materials, or by contaminated plants and animals. | Candidate Set Criteria 1, 2, 3 |
| (A3.0-6) | Chemical forms and physical characteristics of radionuclides, such as solubility and sorption rates, shall be considered to the extent that migration rates are affected. This consideration shall include probable modifications of the original contaminants' characteristics as contact is made with soils, groundwater chemistry, and other contaminants. | Candidate Set Criterion 2 |

| | | |
|---|---|---|
| (A3.0-7) | Decay of radionuclides during transport shall be evaluated. | Candidate Set Criterion 3 |
| A.3.1 Required Candidate Transport Paths Set | | |
| (A3.1-1) | The Candidate Transport Paths Set shall be formed by identifying all potential paths for contaminant migration from existing and projected inventories to the Columbia river. | Addressed for atmospheric pathways in Candidate Set Criterion 1 |
| A.3.6 Contaminant Migration in Air | | |
| (A3.6-1) | Wind patterns within the Columbia River watershed shall be assessed and documented. Wind pattern data provided by the State of Oregon shall be evaluated. | Study Set Criterion 1 |
| (A3.6-2) | The effects on the Columbia River from deposition and redeposition of airborne contaminants from the Hanford Site shall be identified. | Study Set Criterion 3 |

**APPENDIX F. RISK AND IMPACT**
**PG DOCTOR, BA NAPIER**

# Risk and Impact Criteria

## (CRCIA PART II, A6-A9)

### *Outline*

1. General CRCIA and Other Principles
2. Criteria for Selection and Completeness of Ecological Effects, Environmental Functions & Services, Environmental Units of Selection, and Ecological co-stressors
3. Candidate Set for Ecological Effects, Environmental Functions & Services, Environmental Units of Selection, and Ecological co-stressors
4. Criteria for Selection and Completeness of Health Effects, Human Receptors, Pathways and Co-risk Factors
5. Candidate Set for Health Effects, Human Receptors, Pathways, and Co-risk Factors
6. Criteria for Selection and Completeness of Socio-cultural Effects, Socio-cultural Units of Selection, and Socio-cultural co-stressors
7. Candidate Set of Socio-cultural Effects, Socio-cultural Units of Selection, and Socio-cultural co-stressors
8. Criteria for Selection and Completeness of Economic Effects, Economic Units of Selection, and Economic co-stressors
9. Candidate Set of Economic Effects, Economic Units of Selection, and Economic co-stressors
10. Criteria for input needed from the inventory and transport modules

*"The goal is not to be completely accurate about the picture of tomorrow, but to make better decisions about the future."*

Paraphrased from Peter Schwartz
The Art of the Long View, 1996

1. **<u>General CRCIA Principles and Additional Principles</u>**

   a. Candidate and study sets must both be "complete"

- "Complete" is not clearly defined, but may mean that enough information is produces that we can tell the whole story about Hanford and make good decisions. The specific decisions that need to be made are also undefined but are related to closure.

   b. Individual requirements are based on CRCIA Part II, regulations (compliance), trusteeship (e.g., metrics for predicting or measuring natural resource injury or lost human uses of natural resources), Treaties, and general public interests/values.

   c. The <u>rules for moving from candidate sets to study sets</u> are related to

- Most important is to maintain completeness
- Second, balance among dominance, accuracy, precision, uncertainty
- Third, financial constraints
- On the whole, completeness is more important than precision (i.e. sacrifice precision over the whole candidate set rather than reducing the number of items in the candidate set).

   d. The <u>steps for moving from candidate to study sets</u> are:
      - Identify relationships between items in the candidate set through influence diagrams
      - Identify independent and dependent variables
      - Sensitivity analysis of independent variables (this may be quantitative, qualitative, or BPJ as long as the logic is explained)
      - Identify constraints (people, time, funds, models)
      - If necessary, cluster variables into classes (rather than screening any out yet)
      - Identify surrogates and scaling factors for classes of variables
      - If screening out is still necessary, choose between (a) prioritization with exclusion and (b) further clustering (this rule needs to be negotiated)

   e. Performance metrics for "credibility" need to be developed and tracked.
      - Credible process is needed
      - Credible conceptual model is needed
      - Credible science is needed with preservation of disparate opinions
      - What is the Value of Credibility?
      - What is the relation of credibility to completeness? Can incomplete or imprecise analyses still be credible?

   f. Rules for the use of expert judgment need to be developed. This applies to both technical experts (e.g., modelers, ecologists) and cultural experts (e.g. tribal elders).

   g. Differences of opinion, particularly from normally silent voices, must be protected.

   h. The attributes for a "minimal credible model" must be defined.
      - What is the Value of Any (Partial) Information,
      - What is the Value of Good Information
      - What is "good" information and to whom is it useful?
      - What decisions will different parts of the results be used for, and by whom?

- What sequence of information is needed, and what is the schedule of increasingly precise iterations? Does the Long Range Plan tell us this?
- What is the cost of incomplete or inadequate or imprecise information?

i. Temporal and spatial scales must be selected and assumptions must be jointly determined with regulators, tribes, and stakeholders. The spatial scale is a function of ecosystem characteristics, contamination footprint size, and units of closure. The timeframe of the analysis is a function of the hazardous/radioactive lifespan of the material and/or the effect and the time when different receptor locations and exposure scenarios apply.

j. The overall goal is to tell a complete story about the effects that Hanford contaminants could/will have on specific locations and habitats.

k. Receptors include humans, plants, animals, intruders, economies, cultures, activities, religions, gene pools. (A7.0-1 to A7.0-6, A8.3-2)

l. Because relevant ARARs also include Treaties, Principles of Trusteeship, and Environmental Justice, the distribution of effects between different populations need to be kept in mind.

**General outline for identifying candidate and study sets:**

A. Criteria for Complete Candidate Set
B. Criteria for Study Set
C. Issues
D. Scoping studies needed to get from candidate sets to study sets
E. Resources needed (people, skills, models, data, S&T)

### GENERAL PRINCIPLES FOR SELECTING STUDY SETS

In order to included in a study set, a metric or measurement endpoint should:

1. measure the "right" information, either directly or indirectly. If indirectly, the linkage between the true metric and the surrogate measurement must be clear;
2. represent the whole problem when considered along with all the other metrics, and there should not be duplication of measurements;
3. have enough measurement flexibility so they can be used for probablistic as well as deterministic and qualitative evaluations;
4. bound the likely benchmarks or acceptable impact levels for each measure (for example, "dose" measurements should preserve the full range of doses so that different dose standards based on different drivers will be encompassed);
5. contain enough precision or resolution that they help discriminate among options yet not be unnecessarily complex;
6. be amenable to being rolled up, through the use of dependency webs, in the risk characterization step for location-specific impacts
7. must supply information really needed to make key decisions that are technically defensible, "credible," acceptable, and stable.

## **2. Process for developing location-specific dependency webs**

The general approach to **evaluating location-specific impacts** is to

a. Identify locations according to contaminant transport results and knowledge of environmental characteristics [antecedent modules will do this];

b. Describe the existing habitat quality absent Hanford contamination (e.g. pre-existing contaminant burden, existing stressors, critical ecological characteristics, critical human uses, and so on.
   - What makes the place important (to anyone)
   - Who/what lives there or exists there (people and biota; what is the existing environmental quality or usability; what environmental quality or functions or species have already been lost there; what would be expected there but isn't; what trends in environmental quality can be described there?)
   - Who/what uses the location
   - What happens there (ecological migratory stop, human recreation, etc.)
   - What environmental goods, functions, and services are provided by the location and its natural, cultural, economic, and human resources?
   - What is "at stake" there if contamination arrives?
   - Who/what is already "at risk" there for non-Hanford reasons (biota, cultural activity, economic)
   - How are the above factors combined into each locations' descriptive dependency web (influence diagram)?

c. Identify the critical parameters (candidate and study sets) that need to be evaluated for each major location according to the relational web of ecological and human elements that are most important for that location and most likely to be affected by new or additional contamination (i.e., draw the web for the location).

**3. Criteria for Ecological Effects, Environmental Goods, Functions & Services, Ecological co-stressors**

**Note: each study location will have unique "sets"**

***Criteria for complete Candidate Sets***

1. "All" species at each habitat location must be considered,
   - T&E,
   - species of nutritional, commercial, cultural, recreational, aesthetic concern
   - species key to a foodweb or to ecosystem structure or function
2. "All" trophic levels present at each location must be retained
   - individual organisms
   - population, assemblage, community, ecosystem, landscape
3. "All" spatial scales relevant to each location up to and beyond the size of the contamination footprint must be retained, keeping major linked systems together even if outside the footprint
4. "All" impacts at each location must be considered
   - *ecotoxicity for individual organisms*
   - *NRDA injury-type metrics must be included*
   - *service-acre-years for widespread contamination and impacts to environmental functions and services,*
   - *Index of habitat function (several indices have been developed to choose from)*
   - *Other individual metrics according to the habitat and species involved: taxa richness, relative abundance, habitat fragility, genetic diversity, individual condition, production, community structure, species diversity, biomass, processes, population size or density, population age structure, trophic structure, growth rate, species composition, biomarkers, tolerant or intolerant species presence*
5. "All" environmental goods, functions, uses, and services at each location must be considered (check with Mike Scott and Jim Karr)
   - Goods are tangible items of value to plants, animals, or people, such as food and medicine obtained from the location
   - Functions are dynamic roles that elements of the local area play within the area or within a larger ecosystem. Examples are nutrient production needed by local fauna and migratory birds.
   - Services are process or ends of importance to people, such as soils stabilization provided by intact groundcover which in turn reduces dust and associated visibility reduction and cleaning costs.
   - Uses are things people or animals do at the location that are dependent on natural resource quality, such as recreation or public water intake or seasonal nesting grounds for birds.
6. "All" ecological co-stressors specific to each location must be identified.
   - Extraneous chemicals (e.g. heavy metals in sediment, agricultural runoff in surface water)

- Physical stresses/threats to the local habitat or ecosystem or resource
- Biological stresses (e.g. invasive species)
- Other bio-geo-physical stresses (thermal, other?)

A. Criteria for Study Sets

- Choose among indices of habitat function relevant to each location
- Select foodweb model with (negotiated) trophic level detail
-

C. Issues

1. Temporal and spatial scales of species and ecosystems
2. Quality of models/webs for various habitat types
3. The degree of specificity (individual species, trophic levels, microecosystems, and so on must be determined.
4. Criteria for "adequate" Index of Biological Integrity (IBI)
5. What ecological benchmark is most useful? (x Rad/day, LOEL, LOAEL, NOEL, $LC_{50}$ ?)
6. Acceptable degree of impairment at individual through landscape level is what?
7. Stochastic/Deterministic issues; statistical criteria for showing an effect
8. State of the national art is not clear
9. How do we identify trends in ecological quality and what is the least degree of impairment can we detect?

D. Scoping studies needed to get from candidate sets to study sets

TBD

E. Resources needed (people, skills, models, data, S&T)

TBD

4. Candidate Set for Ecological Effects, Environmental Functions & Services, Environmental Units of Selection, and Ecological co-stressors

| Candidate Units of Selection (species, trophic levels, ecosystems) | |
|---|---|
| • Individual species or simple foodchains | A.7.3-5 |
| • Foodwebs and communities | A.9.1-1 |
| • Ecosystems | A.9.1-1 |
| • Species of varying homerange sizes; intrusion and dispersion pathways such as tumbleweeds, burrowing animals, etc. | |
| • Ethno-habitats | A7.1-16 |
| • Keystone or indicator species | A7.1-16 |
| • Species that specifically bioaccumulate certain contaminants | |
| **Candidate Environmental Goods, Functions, Uses, and Services** | |
| • Ecotype- and Location-specific<br>• | |
| **Candidate Set of Ecological Effects** | **CRCIA Requirement** |
| • Contamination or degradation of environmental media (concentration and area or volume affected, and duration of effect or time to recovery) | A.9.1.1-1 |
| • Ecotoxicity to individual organisms of selected species both at the location and whose homerange or migratory range touch the affected area (keystone ecological species, T&E species, culturally important species, indicator and sentinel species). | A.9.1.1-3, A.9.1.1-6, A.7.1, A7.1-15 |
| • Population stability, competition effects, species abundance, species diversity, species distribution. | A.9.1.1-11, A.9.1.1-1, A.9.1.1-15<br>A.9.1.1-11 |
| • Sub-lethal effects such as endocrine disruption, tissue damage, enzyme alterations, behavioral modification, and other markers of natural resource injury in individual organisms. | A.9.1.1-10, A.9.1.1-13 |
| • Mutagenicity in animals, fish, birds; effect on the gene pool<br>• Ecotoxicity to communities, populations, including indirect effects such as whether the location provides nesting cover, nutrients for other species, other things) | A.9.1.1-2, A.9.1.1-5, A.9.1.1-7, A.9.1.1-8,<br>A9.1.1-9 |
| • Effects over successive generations from exposure to long-lived contaminants as they recycle through the environment<br>• Reproductive capacity over multiple generations<br>• Biodiversity and ecosystem integrity (keystone species, other indicators of environmental quality, functionality, and stability)<br>• Habitat functions and services (soil stability, biofiltering, | A.9.1.1-9<br>A.7.1, A9.1.1-11<br>A.9.1.1-8, A.9.1.1-12<br>A.9.1.1-1<br>A.9.1.3-4 |

| | |
|---|---|
| etc.)<br>• Habitat fragility<br>• Any identifiable trends in environmental quality<br>• Landscape ecology, landscape functions and services<br>• Aesthetics and visual integrity<br>• Overall index of habitat functionality and quality | |
| Candidate Set of Ecological Co-Stressors at each location/habitat | |
| • Other chemical, radiological contaminants; total ecological contaminant burden from any source<br>• Physical, thermal, and biological stressors; perturbations of the original conditions at the location.<br>• Reserves of robustness, resiliency, viability, sustainability<br>• Political, legal, institutional threats (e.g. zoning leading to fragmentation)<br>• Current quality relative to original or ideal conditions | |

5. Criteria for Selection and Completeness of Human Receptors, Pathways, Health Effects, and Co-risk Factors

A. Criteria for complete Candidate Sets
   1. Receptors
      - "All receptors" means major or unique groups of people who would be affected by contamination at that location.
      - Receptor groups may or may not each have a separate exposure scenario
      - The most-exposed individuals, populations or population segments
      - The most sensitive individuals, populations or population segments
      - Intruder scenarios need to be identified where and when applicable.
   2. Pathways and Exposure Scenarios
      - The MEI/RME individuals, populations, and population segments need to be identified. Their location relative to the contamination is TBD
      - Actual diets must be evaluated (e.g. native foods and medicines for tribal subsistence scenarios, harvested food for migrant workers, etc.)
      - Accidental intruder scenarios must be included (time point TBD)
      - Multigeneration area-under-the-curve doses/risks must be included
      - Community-level total exposure burdens must be included
   3. Effects
      - All contaminants must be included, as well as all their effects
      - Ranges, selected percentile, etc. is TBD
   4. Co-Risk Factors
      - Individual health-related factors (e.g., underlying health, genetics)
      - General community-related factors (e.g. quality of health care)

B. Criteria for Study Set

   ***8 TBD***

C. Issues
   - Multiple contaminants, add radiological plus chemical risks
   - No consensus on target or acceptable dose/risk levels
   - Cumulative risks (all Hanford sources plus other exposures)
   - Risk distributions and comparisons between populations
   - Time scales and temporal resolution
   - Spatial scales and spatial resolution
   - If not all scenarios can be run, will need scaling factors as heuristics
   - Role of current/future land use or institutional controls or physical barriers in determining level of exposure is controversial

D. Scoping studies needed to get from candidate sets to study sets

**TBD**

E. Resources needed (people, skills, models, data, S&T)

   TBD

## 6. Candidate Set for Health Effects, Human Receptors, Pathways, and Co-risk Factors

| Human Exposure and Dose | CRCIA Requirement |
|---|---|
| • Construction of exposure scenarios for Native Americans (includes ingestion, social and religious activities).<br>• Specialized use scenarios may need to be developed<br>• Acute through chronic timescales for individuals and seasonal through multigeneration durations may be needed<br>• The MEI and the most exposed fraction of the selected receptor group, the most exposed community, or other group must be selected | A7.6-3 to A7.6-3<br><br>A8.1-4, A8.1-5<br><br>A8.2-4 |
| Health Effects | |
| • Cancer<br>• Hazard Index and hazard quotient<br>• Acute, seasonal (subacute or subchronic) exposures and effects<br>• Reproductive, teratogenic, and developmental effects<br>• Immunological effects<br>• Neurological, neurobehavioral, and neuropsychological effects<br>• Effects on enzymes (induction or inhibition), neurotransmitters, and other physiological or biochemical substances<br>• Mutagenicity and genetic effects (especially in small gene pools)<br>• Endocrine effects<br>• Dermal absorption and dermal effects<br>• Other effects (according to the toxicology of the contaminant)<br>• Population-level exposures (total community contaminant burden, total community health, and community well-being)<br>• Population-level effects in future generations; sum of doses and risks over multiple generations (in the individual and in populations)<br>• Proportion of the community or group affected<br>• Other health indices and indicators, using public health methods related to indirect effects, functionality, psychosocial health, etc. | A9.1.2-6<br>A9.1.2-11<br>A8.1-4<br>A9.1.2-8, A9.1.2-9, A9.1.2-10<br>A9.1.2-11<br>A9.1.2-11, A9.1.2-12<br><br>A9.1.2-11<br><br>A8.3-1, A9.0-3, A9.1.2-7<br>A9.1.2-11<br>A9.1.2-11<br>A9.1.2-11<br>A9.1.2-1, A9.1.2-14<br><br>A9.1.2-1, A9.1.2-14 |
| Candidate Set of Health Variables/Receptors and Pathways | |
| • Age (children, elders, women of child-bearing age, breast-feeding infants)<br>• Gender<br>• Selected percentile (mean, $95^{th}$, other) for the maximally exposed individual | A8.3-1<br>A8.3-1<br>A8.1-3 |

| | |
|---|---|
| • Selected community activity or lifestyle (subsistence resident, hunters, basketweavers, others as indicated by affected habitat types).<br>• Individuals who receive extra exposure such as gatherers/preparers<br>• Other groups with more distant exposures (such as consumers or members of extended families and trade networks) with many members.<br>• Effects on populations over time.<br>• Unique cultural activities such as use of the sweat lodge<br>• Other standard community or social activities such as recreation, other CERCLA or site-specific scenarios such as hatchery or stewardship workers, people with unique exposures such as farm workers | A8.0-2<br><br>A8.1-5, A9.1.2-1<br>A9.1.3-4<br><br>A.9.1.2-1 |
| Candidate Set of Co-Risk Factors | |
| • Multiple exposures (additional contaminants from same or other concurrent or prior sources including background, including occupation, and synergism between contaminants, including metabolic byproducts or environmental degradation products)<br>• Biochemical genetics and ethnopharmacology<br>• Underlying health effects (individual or population, using health statistics where available)<br>• Nutritional status and dietary quality, including affects of substitute diet if the traditional diet is unavailable<br>• Socioeconomic status<br>• Access to health care, insurance, and education<br>• Cost of treating illness or avoiding exposure<br>• Suitability of nutritional or medicinal alternative<br>• Health and psychosomatic effects of lost religion, impaired family health, impaired cultural practices, etc. | A.9.1.2-3 |

**7. Criteria for Selection and Completeness of Socio-cultural Effects, Socio-cultural Units of Selection, and Socio-cultural co-stressors**

### *B. Criteria for complete Candidate Set*

1. Socio-Cultural Effects (metrics)

- Indicators of societal well-being (not economic) including access and use
- Indicators of cultural quality of life
- Matrix of cultural attributes x severity/duration/proportion/spatial scale/ reversibility (?)

2. Socio-cultural units of selection
    - Unique groups based on ethnicity, history/culture, religion, lifestyle. Examples include Tribes, migrant workers, Asian communities, suburban community as a single social unit
3. Socio-cultural co-risks or co-stressors (not economic)
    - Cultural deficit due to lost access (i.e. present cultural condition)
    - Cumulative inequity (?)

B. Criteria for Study Set

C. Issues
- The number of individual populations identified for analysis must be determined.
- Discounting (Definitely unacceptable to some groups)
- Issue: cultural mitigation
- Cost-benefit to avoid/prevent; minimize; mitigate; compensate/replace
- Unit of selection: community as a social organism
-

D. Scoping studies needed to get from candidate sets to study sets
- How many ways are there to describe a “culture”?
- What are conventional indicators of societal well-being? (start with Comparative Risk literature, government indicators, and social sciences)
- How are cultures unique (e.g., how is tribal culture distinct with respect to how it values a location or resource?)
- Is the matrix with spatial scale, reversibility, severity and duration correct?

E. Resources needed (people, skills, models, data, S&T)

## 8. Candidate Set of Socio-cultural Effects, Socio-cultural Units of Selection, and Socio-cultural co-stressors

| Candidate Set of Socio-Cultural Effects | |
|---|---|
| • Lost access or use of place or resource (duration of loss, percentile of loss relative to original conditions, residual quality if partially lost or not fully restored)<br>• Community well-being and social and family cohesiveness maintained through use of the place or resource<br>• Everyday life and material implements derived from the place or resource, and living and social activities and practices associated with the place or resource<br>• Religious, ceremonial well-being gained through use of the place or resource; effects on the spiritual landscape<br>• Other uses of the site or resource such as education, art, or trade.<br>• Intergenerational continuity in knowledge, language, religious practice, spiritual knowledge, traditions, values, materials, and education related to the place or resource (on-site or adjacent sites)<br>• Physical integrity of historical or cultural resources located in the place or associated with use of the resource<br>• Preservation of future land use options<br>• Preservation of additional values such as sustainability<br>• Contaminated tribal areas, artifacts, ancestral remains, traditional foods and medicines<br>• Cost of medical treatment of exposure<br>• Cost of replacement medicine due to loss of native foods, medicine, and religion<br>• Cost of "takings" of lost profits, lost jobs, lost resources, etc.<br>• Cost of restoration<br>• Cost of lost environmental goods, functions and services<br>• Cost of lost health goods, functions, and services<br>• Cost of lost cultural goods, functions, and services<br>• Cost of lost treaty rights<br>• Cost of lost access or use (acres x degree of restriction x duration)<br>• Cost of contaminated ancestral remains | A.9.1.2-13, A.9.1.2-19,<br>A.9.1.3-1,<br>A.9.1.3-4<br><br>A.9.1.3-2, A.9.1.3-3<br><br>A.9.1.2-18<br><br>A.9.1.2-16<br>A.9.1.2-17, A.9.1.3-4,<br>A.9.1.1-4<br><br>A7.4-4 |
| **Candidate Set of Units of Selection** | |
| • General suburban surrounding area<br>• Native American Tribes and Bands<br>• Groups such as migrant workers, ethnic communities, | A7.4-5 |
| **Candidate Set of Socio-Cultural Co-Stressors** | |

| | |
|---|---|
| • Current adequacy of social services that might increase costs of the impacts proportionally more than in affluent communities<br>• Background health conditions and health statistics<br>• Past history of impacts to specific cultures and peoples and cumulative impacts up to the present<br>• Current cultural “resiliency.” and current quality of treaty rights<br>• Cost of alternatives (if any); cost of mitigating adverse effects.<br>• Preservation of land use options at the location or at adjacent/downstream sites<br>• | A.9.1.2-2 |

Sidebar: How many ways are there to describe a "culture" and societal well-being?

***Attributes of cultures or lifeways, not in any order (not in columns, either)***

| | | |
|---|---|---|
| Demographics | Art | Music |
| Spatial scale: domain, influence zone, political boundaries, ecosystem boundaries, local vs regional view, importance of privacy and personal boundaries | Religion, basis for defining what is sacred | Technology |
| Ways of self-identification as a person and as a people | Spiritual ways of knowinf | Time (ways of measuring, attitude towards, mental model) |
| Ways of naming and classifying | Cognitive ways of knowing | Recreation |
| Ways of knowing | Nutrition | Language |
| Land ethic – value of nature, value of homeland | Medicine (style, delivery, access, etc) | Work, ways of specializing roles, functions that are values for survival, aesthetics, etc. |
| Education (style, quality) | Shelter | Architecture |
| Scale at which knowledge is preserved (book, individual, community) and transferred | Ways of making decisions (decree, democracy, consensus) and who makes the decision | Ceremonies |
| Laws, rules, legal system, enforcement style and goal, way of administering justice/penalty | Unit of decision making authority (individual, family, community) | Traditions, rituals |
| Kinship systems | Unit of survival (individual, family, band, community, society) = "meme" | Science (ways of observing, explaining, predicting, validating) |
| Administrative or governance system and structure | Social or community ways of interacting and maintaining societal function | Numbering system |
| Status system | Clothing style, decoration | Humor |
| Resource base | Value attributed to natural resource, goods, functions, services | Economics (currency, money, valuation, exchange, income, wealth is defined how) |
| Mobility, transportation | General values | Behaviors with value (generosity, control, independence, harmony..) |
| Risk management system | Risk taking, willingness to | Sensory web, aesthetics |

| | | |
|---|---|---|
| and ways of responding to emergencies or uncertainties | experiment, attitude toward new ideas, deliberation process | |
| Value placed on past and future generations | Value of future conditions, future options, future security versus present needs, value of sustainably futures | Relation towards nature and other people (domination, nurturing, etc) |
| Gene pool description | Style of aggression | Stories (role in society and education, style, metaphors, etc) |
| History of the people, community psychology | Grief systems | Ethnicity |
| | | |

**9. Criteria for Selection and Completeness of Economic Effects, Economic Units of Selection, and Economic co-stressors**

### *A. Criteria for complete Candidate Set*

- Suburban economies (e.g., jobs, services, etc.)
- Tribal economies (e.g., trade networks, barter, spiritual currency received from natural resources and a functioning ecosystem)

B. Criteria for Study Set

-

C. Issues

- Specialization of roles within the economy
- Ecological economics and NRDA methods
- Discounting is definitely unacceptable to some groups
- Contingent valuation of "priceless" resources such as sacred sites or loss of place names through denied access; cost of "takings;" cost of contaminated ancestral remains, etc.
- Cost of lost health, cost of restoration, cost to restore degraded groundwater, cost of life, cost of lost cultural use
- Scaling factors or surrogates for valuation (e.g., $$/service-acre-year x severity; $$/Curie left in place; $$/Ci-year; $$/Ci-acres; $$ of stewardship)

C. Scoping studies needed to get from candidate sets to study sets

  ***9 TBD***

E. Resources needed (people, skills, models, data, S&T)

## 10. Candidate Set of Economic Effects, Economic Units of Selection, and Economic co-stressors

| Candidate Set of Economic Effects | |
|---|---|
| • Economic impacts of losing the place or resource (direct impacts of commercial, trade, jobs, services, housing, schools, etc.)<br>• Replacement costs (duration of loss x annual cost x quality and convenience of replacement, x proportion of community members affected by the loss)<br>• Other costs of avoiding exposure<br>• Other costs of "intangibles" and "externalities" using contingency valuation methods without discounting<br>• Other natural resource valuation measurements<br>• Costs to future generations, such as monitoring and surveillance costs, or increased remediation and restoration costs if contamination spreads or the resource is impaired. Permanent loss may mean infinite costs or requirements for permanent mitigation. | A.9.1.2-20<br><br><br><br><br>A.9.1.3-4 |
| Candidate Set of Units of Selection | |
| • General suburban surrounding area<br>• Native American Tribes and Bands<br>• Ethnic groups such as migrant workers, ethnic communities<br>• Socio-economic groups such as agriculture or tourism<br>• Particular regional activities such as agriculture or recreation | A7.4-5<br>A.9.1.2-22 |
| Candidate Set of Economic Co-Stressors | |
| • Existing SES levels | |

## 11. Criteria for input needed from the inventory and transport modules

## 8 System-Level Model

- Must be the first step, in parallel with design of the Project to handle uncertainty
- Level of required precision (allowable imprecision) must be pre-determined
- Represents the first analytical deliverable
- Used as a screening tool to determine the level of effort needed to reduce uncertainty among modules, and to refine"study sets" of parameters within individual modules.

**UNCERTAINTY DESIGN**

- System-level statistics must be identified before individual modules begin their gap analysis
- A Value-Of-Reducing-Uncertainty evaluation will guide the work in subsequent modules.

**Final Inventories at a selected timepoint**

- must be complete - nothing omitted for lack of data
- the date at which inventory is frozen, or the attributes of when a "project endpoint" is reached need to be defined.
- in buildings, disposal grounds, free in the environment
- uncertainties must be identified, with upper bounds and best basis inventory listed
- all sources within Physical Hanford boundaries must be included (including WPPSS, US Ecology, 300 Area, leased/privatized facilities, etc.)
- any source excluded from the analysis must be clearly identified; an agreement as to the exclusion is necessary with regulators and stakeholders.
- Off-site contaminants (e.g. upstream mining waste, agricultural runoff upstream and downstream, local discharges (Toxics Release Inventory) and NPDES permits should be identified, and data about existing sediment concentrations (B-State and CRU reports) should be used as part of the cumulative impacts evaluation.
- the degree of chemical speciation needed by the transport and risk models needs to identified.
- All curies need to accounted for, and inventory suspected but not verified needs to be identified so it can be included (e.g., plutonium in vents, sand filters, and "lost").
- Curies estimated as past practice sites, past tank leaks, and so on needs to be used even if unverified.
- Existing groundwater contamination must include all those areas above detection limits, even if below drinking water standards.
- Curies left in "closed" facilities such as the PUREX tunnels or Canyon buildings needs to be included.

**Containment and Release Characteristics and Assumptions**

- Assumptions about barrier performance needs to be discussed with RST
- Release form may use simple factors (liquid, powder, solid), or may use data from performance assessments, but must be reviewed by RST
- Containment failure scenarios over the hazardous/radioactive lifespan of the material needs to be developed

**Vadose Zone Modeling Requirements and Assumptions**

- Must account for non-linear transport (lateral, fractures,,,)
- Must include geochemistry (e.g. alkaline, thermally hot, chelation, etc.) only to the level of precision identified as required by the Uncertainty Task.

**Groundwater Modeling Requirements and Assumptions**

- Must account for northward flow
- Must be 1-D, 2-D, or 3-D as required to produce the required information (system-level model might use only 1-D results)
- Must provide flux rate to pore water and the river TBD timescales
- Must identify points of maximum concentration on-site

**Discharge to the River and River Modeling Characteristics and Assumptions**

- Must be able to identify areas of likely reconcentration (slackwater)
- Must show sediment deposition behind dams
- Daily flow cycles as well a seasonal cycles must be accounted for
- Must include biotic transport capability
- Must include sediment absorption/desorption capability
- Must include evaporation at turbulent locations (turbines, dams)
- Must include laminar flow

**Basic Information Needs About Environmental Concentrations**

- Where, when, how long per plume, areal extent
- Peak groundwater concentration per grid cell or per source per contaminant
- Plume maps with boundaries defined by detection limit
- Plume durations
- Downriver hotspots for sediment or surface water

APPENDIX G. ASSESSMENT (EXTREME) SCENARIOS

AL BUNN, LW VAIL

### CRITERIA FOR THE ASSESSMENT SCENARIOS

## *9 Working Rules and Observations*

***Same as those in the Inventory Technical Element***

## *10 Criteria for the Assessment Scenarios Candidate Set*

The criteria for the Assessment Scenarios candidate set is based on the driving forces for moving contaminants to the Columbia River or to receptors. These scenarios will "depict the maximum credible impacts from Hanford". The approach for defining the candidate set is to define the future events that would change the driving forces for contaminant flow to receptors. An example of a driving force would be increased source of water that increases the exposure of contaminants to the receptors. Driving forces could come from changes with the Columbia River, changes in climate, geologic events, or changes in demographics.

Criteria to determine the Candidate Assessment Scenarios include:

- Maximum credible impacts from groundwater recharge rates
- Maximum credible impacts from contaminant dilution by groundwater or Columbia River water
- Maximum credible impacts from remobilization of Columbia River sediment
- Maximum credible impacts from changes in receptors, either through loss or introduction of species (may be covered in Risk module)
- Waste containment performance (similar to Performance Assessment Scenarios)
- Changes in demographics along river corridor
- Changes in Hanford Site disposition baseline (e.g., loss of institutional controls or increased inventories of waste material)

Preliminary Candidate Assessment Scenarios

Identification of the "maximum credible impact scenarios" should be based on the probability of the event and the time frame when the event could occur. Possible impact scenarios include:

- Catastrophic Columbia River floods (not associated with near-term climatological changes, e.g., catastrophic loss of upstream dams)
- Near-term climate change
- 1000 year rain event
- Catastrophic earthquake
- Loss of institutional controls on the Hanford Site
- Loss of receptor (or species)
- Introduction of receptor (or species)
- Demographic change in future use scenarios
- Future plutonium repository

## 11 Criteria for the Assessment Scenarios Study Set

The study set for the Assessment Scenarios would include identification of a set of scenarios that would maximize the driving forces for changing the exposure to receptors. The study set should be a prioritized listing of the candidate set, with emphasis on the higher probability events. Those scenarios selected for the study set should have a at least a one-in-a-million probability and occur within 10,000 years of the site closure.

## 12 Anticipated Scoping Studies

Identify existing information that could be used to define parameters in Assessment Scenarios. Collect such facility related documents as Performance Assessments, Safety Analysis Reports, for information on extreme events. Collect information on flood events and future climatological information. Develop the estimates of the probability of the potential future events and their time horizons.

## 13 Relationship to CRCIA Part II Requirements

The CRCIA requirements listed below have been used to develop the criteria for the Assessment Scenarios Candidate Set.

| CRCIA REQUIREMENTS | | Comments |
|---|---|---|
| A.10 Assessment Scenarios: Columbia River, Climate, Geological, and Political Changes | | Comment 1. 'Scenarios' in A.10 refer to 'regional scale' scenarios and generally long time scales (>50 years). Examples of scenarios included are persistent climatic changes (shifts in recharge and vegetation), extreme hydrologic events (floods), geomorphic evolution (changes in river channel), changes in Columbia River system (removal of dams), political changes (loss of institutional control, loss of cleanup funding), demographic changes (regional population growth), ecosystem changes (Northern Pike). Examples of scenarios not included are moving waste from Site A to Site B, installing barrier on Site X, exposure scenarios. Are scenarios not included adequately addressed in other sections? |
| (A10.0-1) | A set of scenarios that depict the maximum credible impact from Hanford shall be defined. | Comment 1. '*Maximum credible impacts'* implies the *maximum impact* that is *credible*, as opposed to, the *impact* that is *most credible*.<br>Comment 2. A broad set of credible scenarios must be defined and the respective impacts assessed before a subset of maximum credible impacts can be defined.<br>Comment 3. 'Credible' will be defined by criteria established in small working group. See A!0.1-1<br>Comment 4. If dependency webs result in non-quantifiable impacts, how will 'maximum' be assessed.<br>Comment 5. How is 'maximum' defined with multiple incommensurable impact metrics? (Individual attribute maximum or pareto maximum?) |
| (A10.0-2) | Credible scenarios with parameters that depict increased consequences from Hanford contaminants shall be identified to establish a set of scenarios for use in a comprehensive assessment. | Comment 1. "Increased consequences" implies "maximum impact".<br>Comment 2. As opposed to an assessment for an individual site, in a comprehensive assessment the superposition of multiple impacts (i.e. superposition of plumes, etc) will likely make it non-trivial to define the parameters for the maximum impact scenarios. Therefore, a broad set of credible scenarios must be defined and the respective impacts assessed, albeit in some limited fashion, before a subset of maximum credible impact scenarios can be defined.<br>Comment 3. "Increased consequences" will be considered relative to collateral impacts (e.g. Hanford's waste would not be a big concern after a meteor hit the site.) |
| (A10.0-3) | The limited set of scenarios to be evaluated shall include waste containment performance corresponding to the current Hanford Site disposition baseline for cleanup. (See Section II-A.11.) | Comment 1. "current Hanford Site disposition baseline" implies PA scenarios. |
| (A10.0-4) | The set of scenarios to be evaluated include potential demographic changes for the river corridor area under study. | Comment 1. Possibly belongs to Risk section.<br>Comment 2. Suggest it be moved to 10.0-5e.<br>Comment 3. Redundant with 10.0-5d. |
| (A10.0-5) | Scenarios to be assessed shall include, but not be limited to, the following: | Comment 1. Clarify "assessed". Does "assessed" refer to those included in Candidate Set or Study Set? Note similar wording of 10.0-6. |
| | a. Scenarios that depict the groundwater recharge rate in a way that the maximum credible impact from Hanford is assessed. Examples are climate change, future site uses including irrigated agriculture, and river channel changes. | Comment 1. Accepted. |
| | b. Scenarios that depict contaminant dilution by groundwater or Columbia River water in a way that the maximum impact from Hanford is assessed. Examples are flood and drought | Comment 1. Add "credible" to maximum impact (i.e. maximum credible impact) |

| CRCIA REQUIREMENTS | | Comments |
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| | scenarios, upgradient injection or extraction, disposition of present or new dams, and geologic events. | |
| | c. Scenarios that depict enhanced remobilization of sediment in a way that the maximum impact from Hanford is assessed. Examples are future dredging, disposition of present or new dams, and river channel changes. | Comment 1. Add “credible” to maximum impact. |
| | d. Scenarios that depict potential changes in receptors. Examples are future Hanford land-use scenarios, Hanford Site accident scenarios, transportation accident scenarios, demographic scenarios, economic scenarios, institutional evolution scenarios, and cultural evolution scenarios. | Comment 1. Suggest that this be moved to Risk section. It is not consistent with the spatial scales considered throughout the rest of this section. |
| (A10.0-6) | Scenarios to be identified shall include, but not be limited to, the following: | |
| | a. scenarios involving increased inventories of dangerous materials at Hanford, such as a projected future plutonium repository | Comment 1. “Dangerous materials’ refers to any ‘resource or product’ that if released to the environment would be considered a waste or contaminant. |
| | b. scenarios depicting the impact of newly introduced foreign species, such as the introduction of Northern Pike | Comment 1. Dependency webs will deal with dynamics of ecosystem to various stresses. |
| | c. scenarios depicting loss of institutional control over the Hanford Site after various time periods; the full range of probable times for loss of institutional control shall be evaluated. | Comment 1. Accepted |
| | d. scenarios depicting loss of cleanup funding | Comment 1. Accepted |
| | e. scenarios depicting the future production of radionuclides and other new missions for the Hanford Site | Comment 1. Accepted |
| | f. scenarios depicting ecosystem changes | Comment 1. Combine with 10.0-6b |
| A.10.1 Required Candidate Scenarios Set | | |
| (A10.1-1) | The Candidate Scenarios Set shall be formed by including all the scenarios of potential concern. | Comment 1. Add “credible” to maximum impact. |
| (A10.1-2) | Criteria for completeness of the range of scenarios to be included in the Candidate Scenarios Set shall be established in consultation with the System Assessment Capability Team and shall be subject to its approval. | Comment 1. Agreed upon standard break up and assignments. See instruction 2 of instructions for preparation of Draft Matrices (October 21, 1998).<br>Comment 2. A small working group will be created to draft completeness criteria. Approach for approval to be defined by the policy group.<br>Comment 3. Criteria for “credible” and “maximum” will be drafted by small working group. |

## APPENDIX H. HANFORD SITE DISPOSITION BASELINE
**CT KINCAID**

Candidate Hanford Site End-State Set – Development pending completion of ongoing review of assumed end-states used as basis for Hanford Site closure-cost estimate.